February 1960

75¢

SEMICONDUCTOR PRODUCTS

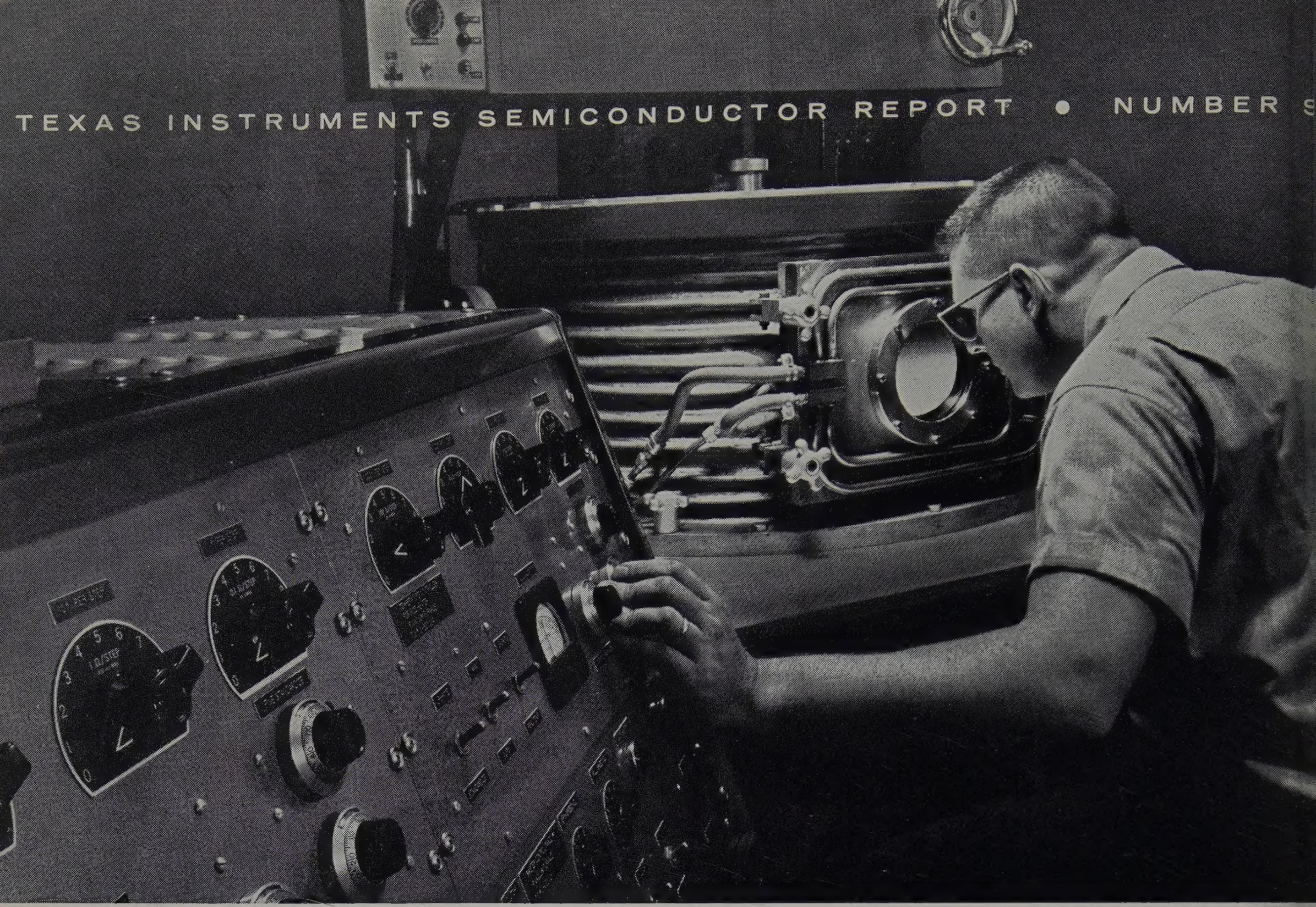
Infrared Scanning System

Measurement of Switching Transistor Parameters

Saturating and Current Clamped High Frequency Pulse Circuits

Semiconductor Diode Switching Characteristics

A New Technique For Computer Switching



Giant crystal puller grows, casts 10-inch silicon crystals at TI

Silicon crystal chalice, produced by combining growing and casting techniques, illustrates capabilities of TI giant crystal puller that grows 10-in. silicon crystals and casts ½-in. plates to 12-in. diameters.

Anticipating and keeping pace with advanced infrared materials requirements, TI engineers designed and built a giant crystal puller capable of growing semiconductor crystals to 10-inch diameters. Designed for engineering and development studies, it can grow a wide variety of crystal configurations, and add further variations to the TI developed cast silicon dome process. The latter method economically casts silicon domes such as those used on infrared guided missiles. This casting of thin silicon shells instead of growing entire crystals substantially reduces material costs and saves considerable grinding and polishing time. Combinations of the growing and casting techniques can be used advantageously to produce many unusual results such as the chalice shown at left.

Only advanced facilities can produce advanced components.

The scope of semiconductor technology at Texas Instruments ranges from the refinement of ultra-pure raw materials through the manufacture of transistors, diodes, rectifiers, infrared detector cells, solar cells, and other infrared optical materials . . . a completely integrated facility to bring you electronic components of the highest known standards of quality and reliability.

germanium and silicon transistors
silicon diodes and rectifiers
tan-TI-cap solid tantalum capacitors
precision carbon film resistors
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INCORPORATED
SEMICONDUCTOR-COMPONENTS DIVISION
DALLAS, TEXAS

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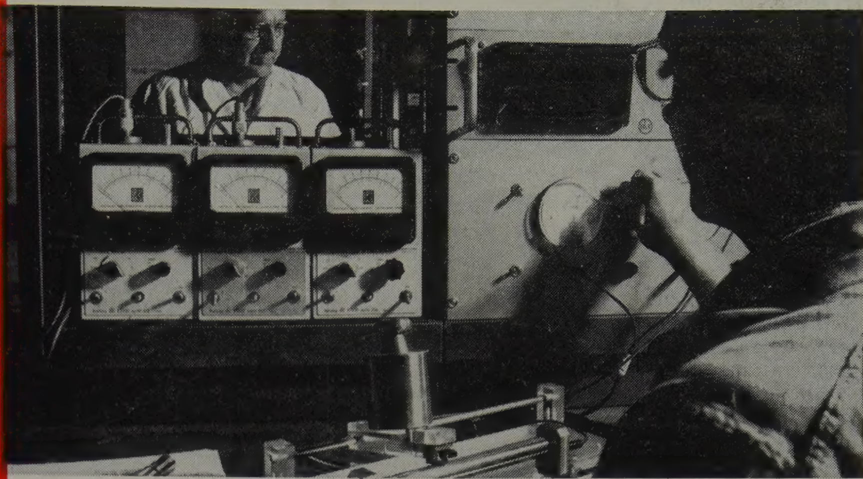
ILGRAY

MERCK HAS ALL FOUR FORMS OF

Silicon

IN PRODUCTION QUANTITIES



Measuring resistivity with digital voltmeter at Merck Control Laboratory, Danville, Pa.

***MERCK DOPED SINGLE CRYSTAL SILICON**—offers doped float zone refined single crystals of high quality at low costs. Yields of usable material are reported to be especially high when device diffusion techniques are used with these crystals. Float zone single crystals doped either "p" or "n" type with resistivities from *0.1 to 300 ohm cm.* any range plus or minus 25% with high lifetimes, available in diameters of 19 to 21 mm., and random lengths of 2 to 10 inches.

NOTE: *Doped single crystals float zone refined in other diameters, resistivities, or lifetimes not listed above can be furnished as specials.*

MERCK HIGH RESISTIVITY "P" TYPE SINGLE CRYSTAL SILICON—offers float zone refined single crystals of a quality unobtainable by other methods. Available with minimum resistivity of 1000 ohm cm. "p" type and a minimum lifetime of 200 microseconds, diameter 19 to 21 mm., random lengths 2 to 10 inches.

MERCK POLYCRYSTALLINE BILLETS—have not previously been melted in quartz, so that no contamination from this source is possible. Merck guarantees that single crystals drawn from these billets will yield resistivities over 50 ohm cm. for "n" type material and over 100 ohm cm. for "p" type material. Merck silicon billets give clean melts with no dross or oxides.

MERCK POLYCRYSTALLINE RODS—are ready for zone melting as received . . . are ideal for users with float zone melting equipment. Merck polycrystalline rods are available in lengths of 8½ to 10½ inches and in diameters of 18 to 20 mm. Smaller diameters can be furnished on special order. In float zone refining one can obtain from this material single crystals with a minimum resistivity of 1000 ohm cm. "p" type with minimum lifetime of 200 microseconds or the material can be doped by user to his specifications.

***NOTE:** *Extended resistivity range.*

BASE BORON CONTENT BELOW ONE ATOM OF BORON PER SIX BILLION SILICON ATOMS

For additional information on specific applications and processes, write Merck & Co., Inc., Electronic Chemicals Division, Department SP-26, Rahway, New Jersey.

Electronic Chemicals Division
MERCK & CO., INC. • RAHWAY, N. J.

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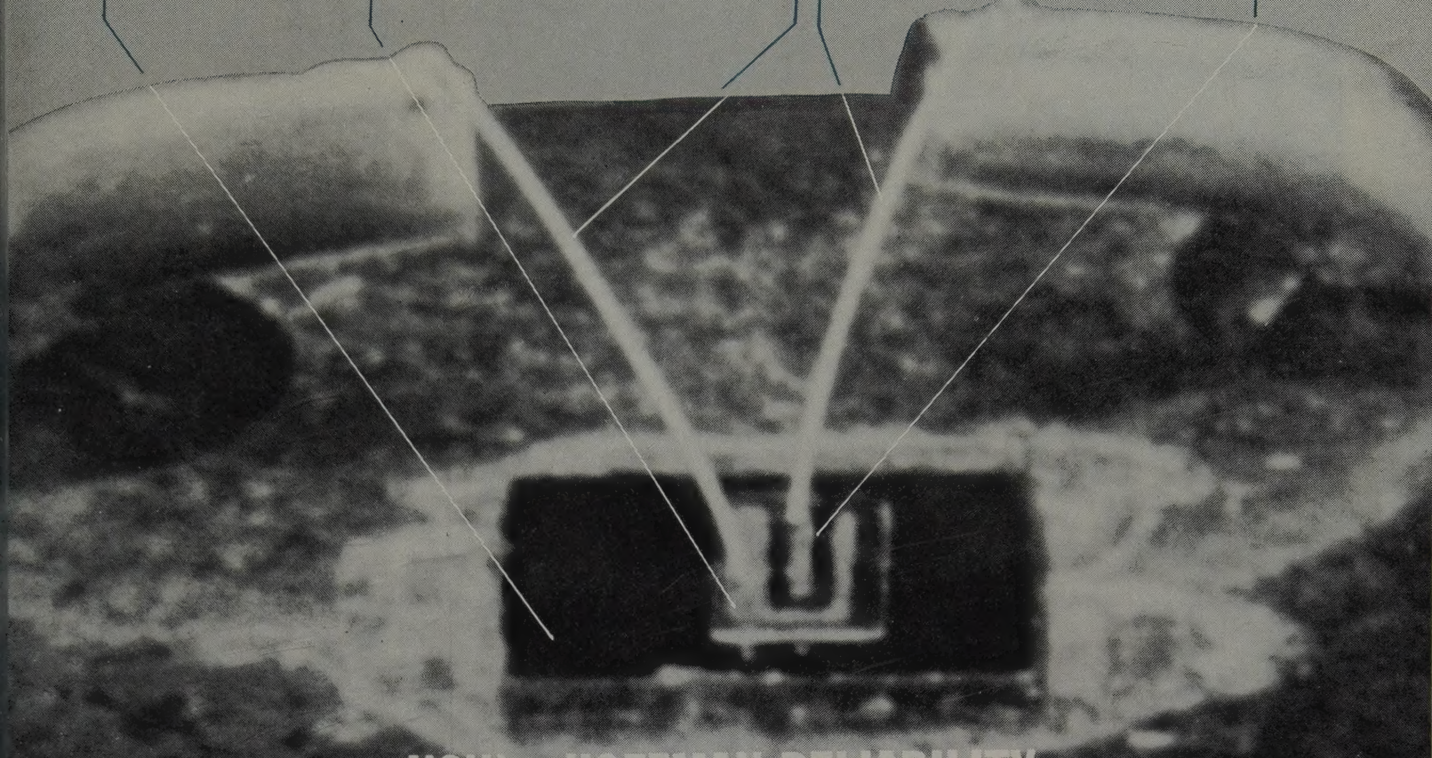
ector is in electrical contact
case.

Base width is reduced to only one micron by precisely controlled lapping and diffusion techniques to boost frequency handling capability. Silicon slices for these transistors are polished under optical control with an accuracy of 4×10^{-6} inch.

Gold wire bonds to emitter and base are fabricated to withstand 20,000G acceleration. Because parts are so small (wires are only 1/10 the diameter of a human hair), bonding is done under a high-power microscope.

Registration of emitter within U-shaped base makes optimum use of emitter area, results in high efficiency. This configuration is made possible by the precision of the Hoffman photographic registration technique.



NOW... HOFFMAN RELIABILITY IN TRANSISTORS

ANNOUNCING THE HOFFMAN 2N696 AND 2N697 NPN DIFFUSED-JUNCTION DRIFT-FIELD SILICON MESA TRANSISTORS

WITH THREE TIMES THE HIGH-FREQUENCY POWER GAIN OF SIMILAR DEVICES

By increasing the usefulness of the emitter area, Hoffman engineers have boosted the minimum high-frequency gain at large currents to 6 at 20 mc ($I_C = 50$ma, $V_C = 10$V)--more than three times the industry standard. Hoffman's unique base-emitter configuration, coupled with a photographic fabrication technique that offers control accuracy of the order of light wavelengths, has also lifted current and frequency characteristics well above industry specifications. Reasonable current gains at 40mc have been measured. Since the photo process is far more controllable than mechanical fabrication, these transistors have exceptionally uniform characteristics. Stability, too, is outstanding, because Hoffman pre-ages every transistor at 300°C and seals it hermetically in an inert-gas atmosphere.

A wide range of useful current gain and operating frequencies makes these units ideal for computer, radar and many other applications. You can count on them in your most important circuit. Reliability is built into every unit.

ABSOLUTE MAXIMUM RATINGS (25°C)

V_{CBO} Collector-to-base voltage	60V
Total dissipation at case temperature 25°C	2W
Storage temperature range	−65°C to +175°C

ELECTRICAL CHARACTERISTICS (25°C)

SYMBOL	CHARACTERISTIC	MIN.	MAX.	TEST CONDITIONS	
h_{FE}	D.C. pulse current gain (2N696)	20	60	$I_C = 150$ma	$V_C = 10$V
	(2N697)	40	120	$I_C = 150$ma	$V_C = 10$V
V_{BE} (sat)	Base saturation voltage		1.3V	$I_C = 150$ma	$I_B = 15$ma
V_{CE} (sat)	Collector saturation voltage		1.5V	$I_C = 150$ma	$I_B = 15$ma
h_{fe}	Small signal current gain at f = 20mc	6	9	$I_C = 50$ma	$V_C = 10$V
C_{ob}	Collector capacitance		35uuf	$I_E = 0$ma	$V_C = 10$V
I_{CBO}	Collector cutoff current		1.0ua	$V_C = 30$V	T = 25°C
			100ua	$V_C = 30$V	T = 150°C

Physical dimensions in accordance with JEDEC 30 (TO-5). Manufactured to meet MIL-S-19500B requirements.

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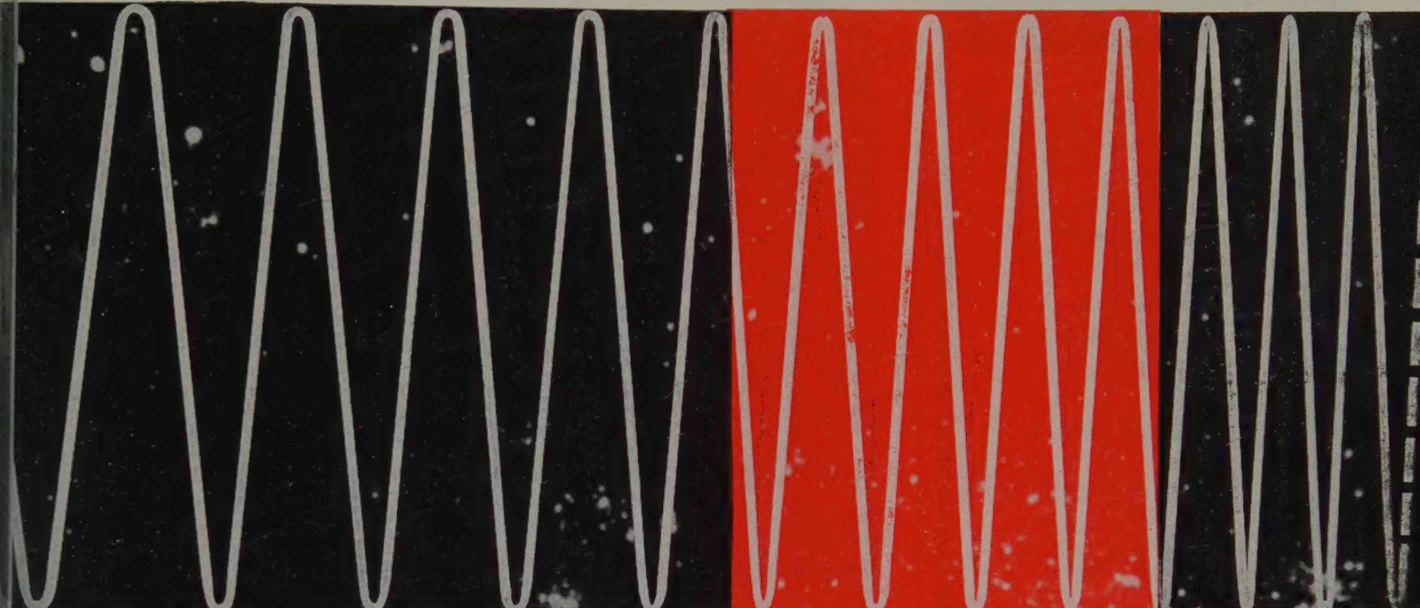
POSTMASTER: SEND FORM 3579 to SEMICONDUCTOR PRODUCTS, 300 West 43rd STREET, NEW YORK 36, N. Y.

Now...PHILCO offers the only commercially available fully-tested mixer diode in the 70 KMC BAND



'or Long-Range Space Communications nd High Resolution Radar Applications

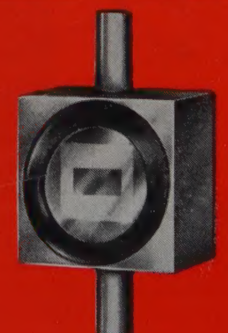
ust de-classified! A proven mixer diode that, for he first time, makes useful the 70 KMC high fre- uency band of the spectrum! Previously, the high- st useful frequency was 35 KMC. The 1N2792 s a reversible crystal designed for optimum low- oise performance. The crystal is of integral wave- uide construction with the diode mounted in a ection of RG-98/U waveguide. It is hermetically ealed for resistance to moisture.

It is primarily designed for high resolution radar pplications and for long-range high altitude or pace communications . . . atmospheric absorption revents jamming from the ground. The Philco N2792 is also well suited for EHF video detector pplications.

Philco design and application facilities are at our disposal in developing millimeter diodes to neet your specific requirements. For complete in- ormation, write Special Components Dept. **SC-260**

est Frequency............................69,750mc

	TYP.	MAX.	
Joise Ratio, NRo	2.0	2.5	times
Conversion Loss, Lc	8.4	10	db
F Impedance, VSWR	1.35	2.0	times
Crystal noise figure, NF	11.5	13	db



1N2792
GERMANIUM MILLIMETER WAVE MIXER DIODE
IMMEDIATELY AVAILABLE

PHILCO®

LANSDALE DIVISION, LANSDALE, PENNSYLVANIA

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SEMICONDUCTOR PRODUCTS

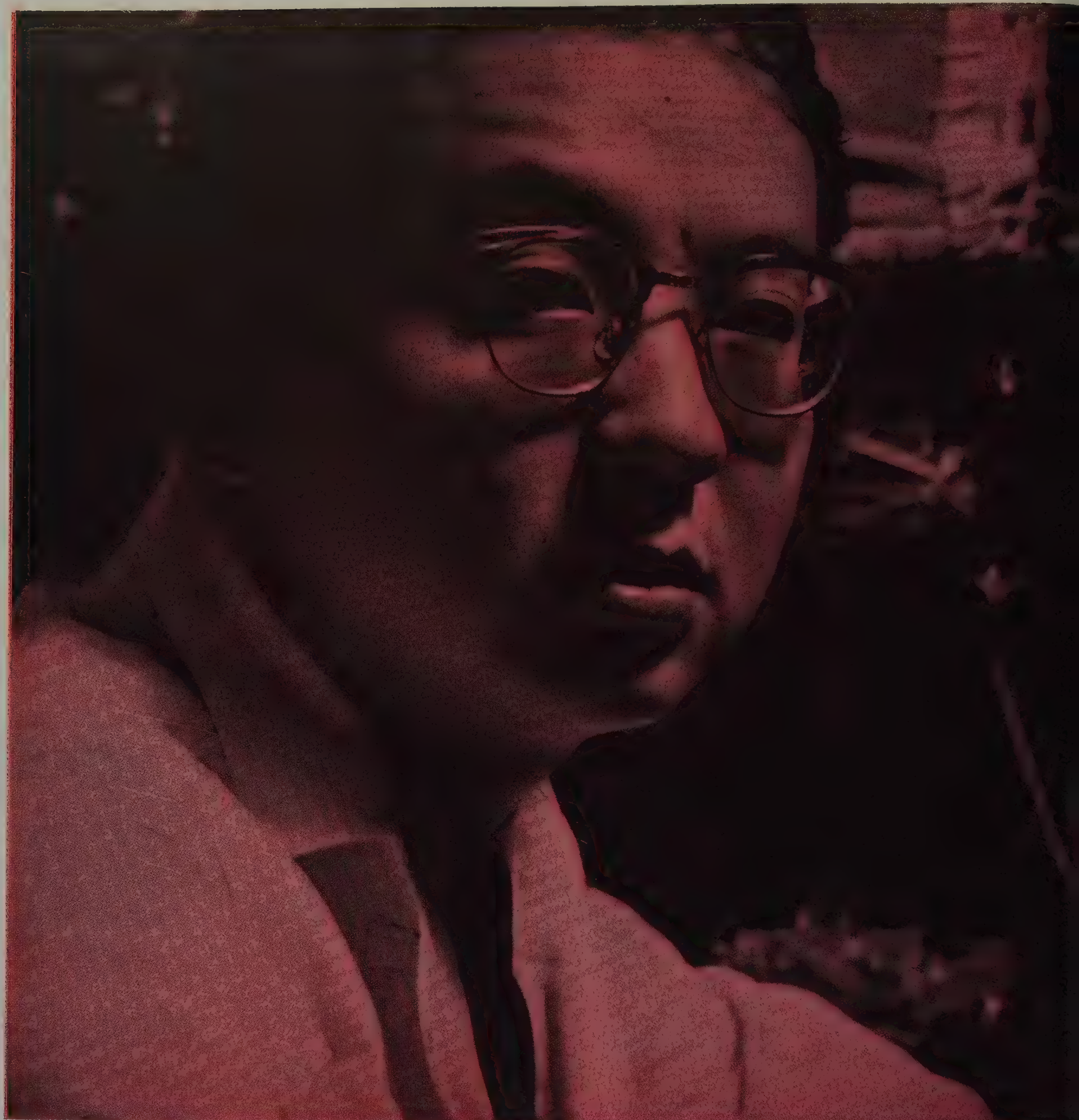
SANFORD R. COWAN, Publisher

February 1960 Vol. 3 No. 2

CONTENTS

Front Cover

Illustrated is the letter "M" displayed on the screen of an all-electronic infrared imaging system developed by scientists at Philco Corporation's Research Division. The infrared image of a given field of view is focussed into a scanning tube which dissects the image. After passing through the scanning tube, the radiation is refocussed onto a separate In Sb infrared detector. The tube face is a semiconductor window.



arkable example of perfectionism can be found
ys Unlimited's p and n type semiconductor pre-
epartment.

rolling mills, for example, used to produce foil,
e able to hold a tolerance of 1/10,000" and better.
ing mill heads are made of high grade stainless
ground with diamond abrasives, to a mirror
finish. Ordinary heads are never used. They
e embedded with impurities and could contami-
e melt.

particular alloys with known contaminating ef-
separate roll sets are used exclusively.

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ducing dies, a team of craftsmen use the same
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e a die is produced, an alloy serial number is assigned. The die is then isolated and used only for your particular alloy; checks cross contamination.

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To assure preform purity Alloys Unlimited uses vapor degreasing and ultrasonic cleaning techniques. Anything less would not fully remove surface contamination and insure preform purity.

THE MOST IMPORTANT TEST

Of course, the final test of a preform's quality is its performance in your semiconductor. Giants of the semiconductor industry have tried and tested Alloys Unlimited's products. Continued reorders indicate complete satisfaction.

If you, too, want to take every precaution to make your semiconductors perform as designed, use the products of Alloys Unlimited. We think you'll be pleased with the results. *Write for complete information.*

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THE INDUSTRY'S FIRST CHOICE

Microtom-atic®

**Reg. T.M. — The DoALL Company. Microtom-atic is taken from the word microtome, defined by Webster as "An instrument for cutting sections."*

for ultra-precision slicing and dicing of semiconductor materials

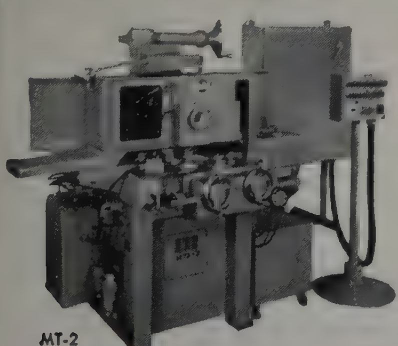
Large silicon crystal being wafered on an MTA-7. Wafers .030″ thick are being cut at 1 sq. in. per min. with parallelism between .001″ and .002″.

Today more than 60% of all transistor elements are being cut on Microtom-atic machines. This industry-wide preference was won through sheer performance — dependable accuracy, high production rates, and trouble-free, continuous-duty operation.

Now the new Microtom-atic MTA-7 brings even greater accuracy and increased production at lower cost. Unique cross-feed mechanism co-ordinates mechanical and hydraulic movements to achieve ultra-precision indexing. Fracture-free cutting of extremely thin wafers with excellent parallelism is no problem on the MTA-7. Simple, accurate controls expedite setup with minimum waste and then the MTA-7 automatically repeats the indexing and cutting cycle until the crystal is completely sliced.

The new MTA-7 is extremely rigid throughout with heavy base, saddle, table and column construction. Long life and continued accuracy are assured through generous bearing areas, hand-scraped ways and positive, automatic lubrication of all contact areas and lead screws.

If your work involves slicing of hard, brittle and shock-sensitive materials, DoALL can help you. Call your local DoALL Sales-Service Store and discuss your problem. A corps of specialists and the DoALL Demonstration Test-Center are at your disposal.



MT-2

Model MTA-7 provides index stroke from 0 to .100″ per index with positive table rates as low as 1/16″ per minute. Other models available.

DoALL diamond slicing wheels are produced by an exclusive process that insures positive rim bond to the core. These wheels deliver extreme accuracy . . . save time and materials.

The DoALL Company, Des Plaines, Illinois

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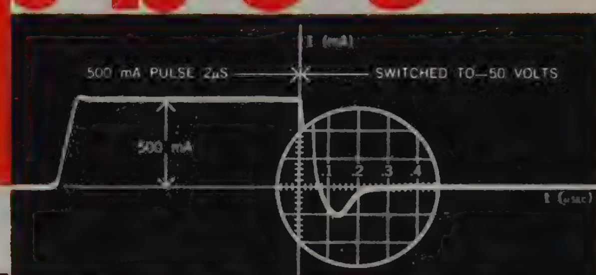
0.5 0.4 0.3 µsec

Fastest recovery yet...



½ AMPERE
SILICON SWITCHING DIODES

. . . in a high-current silicon switching diode. The 1N920-1N923 series is the latest result of Sperry Semiconductor's unique developments for the computer field.

The most advanced addition to the industry's most complete line of high conduction fast recovery diodes, this series meets the severe requirements of high current pulse circuits for high speed computer switching, pulse clamping, gating, blocking, and diode logic circuits.

Designed for high temperature operation (to 175° C), the 1N920 series features high forward conductance (500mA at 1.0V.) and low leakage (50µA at 150° C). Peak dissipation is 800 mw.

All units feature a maximum recovery time of 0.3 microseconds to return to 10K ohms when switched from a forward current 2 microsecond pulse of 500mA to a reverse voltage of —50 volts (—30 V for 1N920), with a loop impedance of 1K ohms. Faster switching speeds are obtained at lower currents.

TENTATIVE DATA

Type	Working Inv. DC Voltage (Volts)	Max. Forward Voltage Drop at 25°C (V.)	Max. Inverse Current (µA) 25°C	Max. Inverse Current (µA) 150°C	Min. Saturation Voltage at 100µA 25°C	Max.* Recovery Time µsec.
1N920	36	1.0 at 500mA	.25	50 @ 30V.	40	0.3
1N921	70	1.0 at 500mA	.25	50 @ 60V.	80	0.3
1N922	100	1.0 at 500mA	.25	50 @ 90V.	120	0.3
1N923	130	1.0 at 500mA	.25	50 @ 120V.	150	0.3

*Refer to Sperry Bulletin No. 2103

SPECIAL SAMPLE OFFER

Order a sample lot for your own application at the special price of only $50 for a lot of 10 1N921 diodes. Direct your order to the So. Norwalk plant or the nearest Sperry sales office as listed below.

SPERRY

SPERRY SEMICONDUCTOR DIVISION, *SPERRY RAND CORPORATION, SOUTH NORWALK, CONN.*

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BOOK REVIEWS . . .

TITLE: Proceedings of the Symposium on Microminiaturization of Electronic Assemblies

AUTHOR: Edited by E. F. Horsey and L. D. Shergolis

PUBLISHER: Hayden Book Company 1959

The Proceedings of the Symposium on Microminiaturization of Electronic Assemblies is a collection of twenty-five of the papers presented at the 1958 meeting held at the Diamond Ordnance Fuze Laboratories of the National Bureau of Standards.

The material is carefully divided into six sections, five of which present papers by experts on various phases of subminiaturization. The first section entitled "Techniques" covers various aspects of the processes involved in subminiaturization. Fine-line etched wiring, resistor and capacitor film development and vacuum evaporation are but a few of the processes described. Chapter IV is an interesting discussion of interconnection of the various microminiature subassemblies followed by a survey of equipment that can be adopted to produce these units.

Section 2, which is simply titled "Semiconductors" presents three papers dealing with the direct incorporation of the transistor element less its casing, into circuitry. Various problems that occur as a result of the direct sealing of the transistor are covered in the first paper by Stinchfield and Meyer. Actual packaging technology and methods, together with a paper on the use of these modules in the Army program, complete this section.

The most useful sections of this book may be found in Sections 3 and 4 dealing with components and circuits respectively. A wealth of material is presented on the development of specialty components. Of particular interest are the treatments of the miniature antennas and miniature microwave magnetrons. The chapters on circuitry are equally enlightening. Standard transistor circuits offering advantages in component size economy are considered and a very useful survey of circuit configurations shows how to eliminate bulky components ordinarily required for low frequency audio applications.

The book concludes with Sections 5 and 6 detailing many of the miniature assemblies as used on various missile systems together with a survey of recent progress made outside the military electronics field.

The Proceedings of the Symposium on Microminiaturization is a very useful book. The techniques described are in most cases readily adaptable to commercial manufacturing. The many photographs clarify the material and add greatly to the concept of scale-size of the microminiature assemblies. The book is well compiled and carefully edited, providing a comprehensive up-to-date review of the microminiaturization field.

TLE: Encyclopedic Dictionary of Elec-
onics and Nuclear Engineering

JTHOR: Robert I. Sarbacher Sc.D.

JBLISHER: Prentice-Hall, Englewood
iffs, N.J.

The Encyclopedic Dictionary of Elec-onics and Nuclear Engineering is a mas-ve 1,417 page reference book offering cid, clear and thorough descriptions of actically every modern electronic or iclear term.

The inherent value of a book of this pe lies in the understandability and otness of the descriptions. In this respect r. Sarbacher has done an excellent job. typical example of this may be found considering the term "Amplifier." ully twenty-three pages of description re needed to consider all possible types, om the various classes to individual pes such as servo, combining and float-g paraphase. Illustrations are many and asic mathematics are used, whenever ecessary, to illustrate a point.

The material given under "Transistors" another example of the type of pres-ntation to be found. Here the equations or the three basic configurations are iven, for the exact case and two approx-nations. In addition a multitude of in-ormation, from basic physics to meas-rement of parameters is covered. The efinitions are clear and the level of iscussion is that of a textbook.

The Encyclopedic Dictionary of Elec-ronics and Nuclear Engineering is a eritable gold-mine of information for ne engineer, technician or student. The ook is thorough, well written and accu-ate and may be considered to be a funda-nental reference work.

TITLE: Progress in Semiconductors Vol-ume 3

AUTHORS: A. F. Gibson, P. Aigrain, R. E. Burgess

PUBLISHER: John Wiley, New York

Progress in Semiconductors is a very iseful compilation of various papers on pecific subjects digested and grouped by opics.

A book of this nature is very useful to he busy engineer since a great deal of ime-consuming research work has been done in the preparation of the various chapters. A typical example of the pres-entation may be found in the chapter on Silicon Junction Diodes. Here in thirty one pages, the reader is brought up to date with the latest concepts and tech-niques concerning the diode. Theoretical behavior is well covered with a review of the basic drift current equations. This is followed by production methods and construction and characteristics of typi-cal diodes, concluding with a section on uses of the device. The material is a compilation of some twenty papers which are listed and footnoted throughout the discussion.

Many other topics are treated in a similar manner. Chemical Purification of Germanium and Silicon, Lifetime of Ex-cess Carriers in Semiconductors, Scatter-ing and Drift, Mobility of Carriers in Germanium are but a few of the section headings.

Volume 3 of this annual series is a high-ly desirable addition to the library of the semiconductor specialist since it presents much information not immediately avail-able in any one paper.

By Stephen E. Lipsky

Editorial . . .

The Diode Equation

Solution of the diffusion equation for p-n junction diodes is generally obtained with the assumption that the carrier flow is unidimensional. The two types of geometries considered usually are the plane junction and the hemispherical junction type. For instance, with reference to hole injection, the hole concentration in the vicinity of the boundary of the junction is

$$p - p_n = p_n\,[\exp(\Lambda V) - 1]$$

in the case of flow parallel to a given direction and

$$p - p_n = p_n\,[\exp(\Lambda V) - 1]\; r_o/r$$

in the case of radial flow from a hemispherical source. In the above relations the quantity Λ is equal q/kT, p_n is the equilibrium concentration, r_o is the radius of the hemispherical junction surface.

These assumed geometries represent approximations, and for this reason the resultant solution must be modified with corrective factors in general. On the other hand it is important that the idealizations introduced for the purpose of mathematical simplification be as close as possible to the actual physical situation. The latter question is subject of speculation for the physicist. In particular, in the case of the above problem, the presence of surface effects is generally responsible for lack of uniformity of the flow. In the hemispherical injection phenomenon this means that the flow of minority carriers is a function of the azimuth angle θ as well as of the radial distance, r. Such an observation has been made recently by Gossick (*J.A.P.*—Jan. 1960) who has proposed that the solution of the diffusion equation in spherical coordinates be made on the basis of higher mode terms, rather than in terms of the lowest "unipolar" mode. Using the simplest of the higher modes, i.e. the "dipole" mode, the hole distribution at the junction boundary is written

$$p - p_n = p_n\,[\exp(\Lambda V\cos\theta) - 1]\; r_o^2/r^2$$

Solution of the diffusion equation provides an expression of the diode equation which presents higher values of the saturation current and lower values of the slope in the forward region. What is more interesting is the fact that the "dipole" mode exhibits a shorter injection recovery time than the "unipole" mode and therefore provides better high frequency operation. Having recognized the properties of this mode, efforts could be made to enhance it.

Samuel L. Marshall

Personnel Notes

Joining Fairchild Semiconductor Corporation, Mountain View, Calif., in newly created production posts are Charles E. Sporck and Lawrence S. Feldman, Operation's Manager Frank Grady announced recently. With Sporck taking over Production Manager's duties, Feldman and Robert Robson, formerly Fairchild's Product Supervisor for the logic transistor line, will serve as Production Superintendents.

Also joining the Palo Alto Research and Development Laboratory is Electrochemist Paul Ignacz. Trained at the University of Budapest, he had industrial and academic experience in that city.

Steve Manning has been appointed manager of the West Coast Sales Engineering Office of General Instrument Corporation. He had been Western Regional Sales Manager of the Advanced Relay Company and prior to that District Sales Manager for Pacific Semiconductor, Inc. The West Coast office (11982 Wilshire Boulevard, Los Angeles, 25) handles sales of products of all General Instrument divisions including the Semiconductor Division (Automatic rectifiers and Radio Receptor diodes).

The appointment of Aldon M, Asherman as manager of market research of the Chemical and Metallurgical Division of Sylvania Electric Products Inc. has been announced by Robert Beatty, general marketing manager of the division. Mr. Asherman has been advertising manager of Sylvania's Chemical and Metallurgical, Parts, and Electronics Systems Divisions with his headquarters in New York City.

The directors of Alpha Metals, Inc., Jersey City, have announced the election of Harold Hertzog as president. Mr. Hertzog moves up to the new post from his former position as vice president of the company.

Martin A. Boyle, field sales manager since 1945, was named vice president in charge of sales.

Rena Shonberg has been elected secretary-treasurer.

Carlo V. Bocciarelli has been appointed associate director of Philco's Research Division, in charge of the Basic Science and Technology Department. The announcement was made by Director of Research Donald G. Fink. Mr. Bocciarelli has been associated with Philco since 1942, and has served as assistant director for Solid State Electronics research since 1957. He received the B.Sc. degree in Chemistry from the University of Florence (Italy) in 1922. Author of several papers, he holds a dozen patents.

Lester Avnet, president of Avnet Electronics Corporation, announced that Clark J. Grey has been promoted to vice president in charge of sales of the Avnet Electronics Sales Corporation, a wholly owned subsidiary.

Dr. Albert A. Canfield has been appointed director of university and scientific relations for the Bendix Aviation Corporation. Dr. Canfield, who has been associate professor of management in the school of business administration at Wayne State University in Detroit, will coordinate the activities of 25 Bendix divisions in the placement program for engineering and scientific personnel, according to the announcement by A. P. Fontaine, vice president.

Sperry Semiconductor, So Norwalk, Connecticut, has announced the appointment of Carl Tishler as an Applications Engineer. He will be responsible for the evaluation and application of advanced semiconductor products for this division of Sperry Rand Corporation. Mr. Tishler has had several years recent experience in semiconductor applications with the Remington Rand Division where he worked on transistorizing computing equipment, including high-speed printers, and was responsible for developments in the area of high-current transistor driving circuits for computer memories.

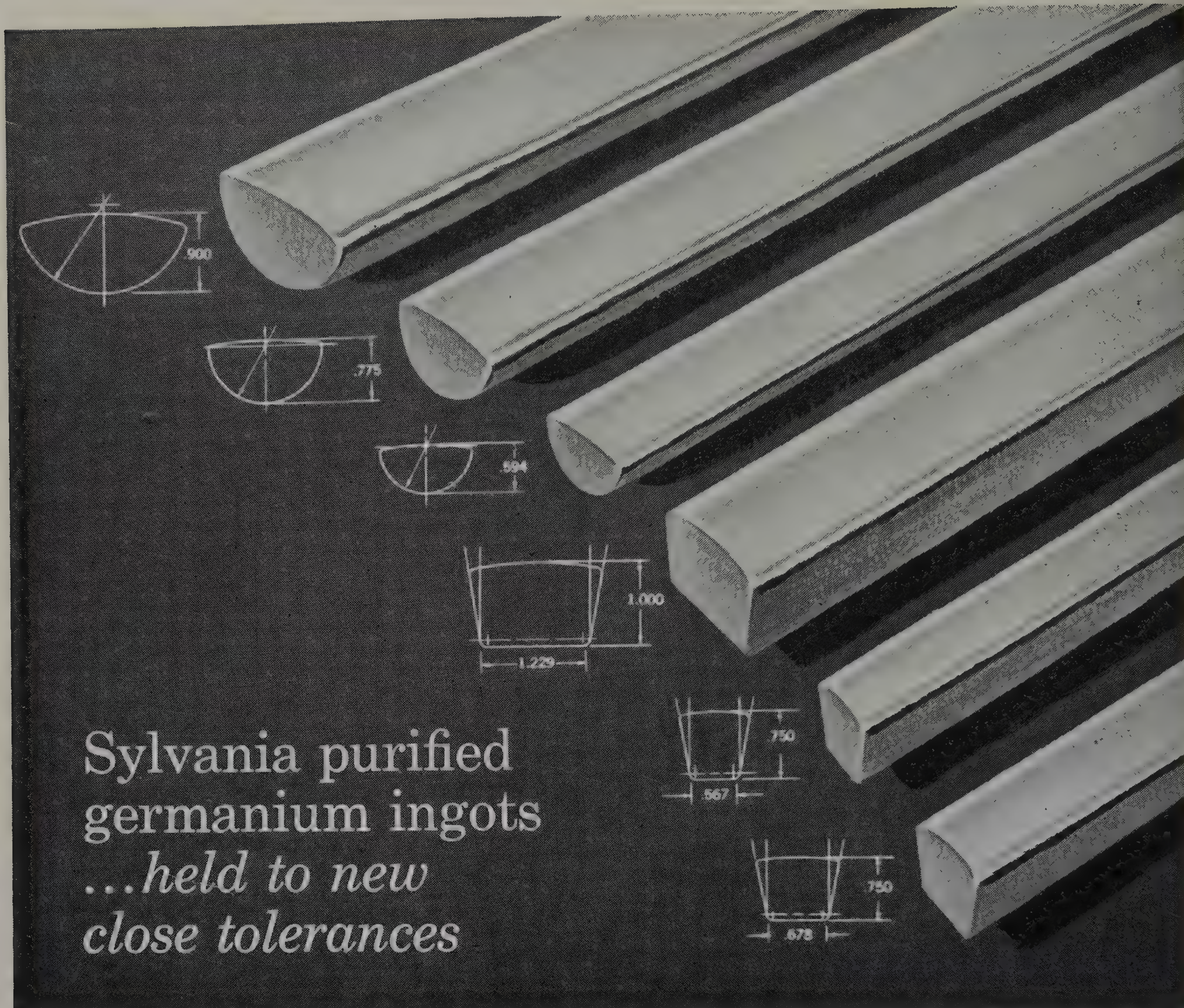
Appointment of William E. Circe as Manager, Plant Personnel, of the RCA Semiconductor and Materials Division's new manufacturing facility under construction in Mountaintop, Pa., was announced by George R. Ritter, Plant Mgr.

Mr. William Leibowitz, veteran metal working executive, has been appointed Plant Manager of Accurate Specialties Co., Inc., Woodside, N.Y. facility, it was announced recently by Mr. Nathan Zimmer, President. He wil be responsible for the expanded production of the company's line of ultra-precise high-purity alloy preforms clad metal components, and precious metal stampings supplied to the semiconductor industry for use in transistors, diodes, and rectifiers.

Dr. M. John Rice, Jr. has been appointed manager of semiconductor material engineering in an announcement by N. L. Harvey, vice president of engineering for CBS Electronics. Dr. Rice was previously director of research for Trancoa Chemical Corporation. Dr. Rice received his B.A. in Chemistry from Alfred University and his Ph.D. in Physical Chemistry from Brown University. He has co-authored several articles published in technical journals, and currently has a patent pending for a method of producing high purity silicon.

Dr. Norman A. Baily, an experienced radiation physicist, has joined Hughes Aircraft Company's nuclear electronics laboratory as a senior staff physicist, it was announced by Dr. John W. Clark, laboratory manager. His work concerns investigation of medical and radiological applications of linear accelerators and detection devices. Dr. Baily came to Hughes after five years as chief scientist for the department of radiation therapy at the Roswell Park Memorial Institute, Buffalo.

Henry F. Schoemehl has been appointed director of engineering of Hoffman Electronics Corporation's semiconductor plant in Evanston, Ill., Maurice E. Paradise, executive vice president and general manager of the Semiconductor Division, announced. Mr. Schoemehl, who succeeds Dr. J. R. Madigan, was formerly the plant's marketing director. He is succeeded in that post by Ben W. Roberts, former field sales engineer for the division in the West Central States.



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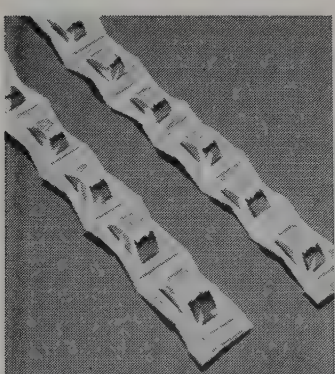
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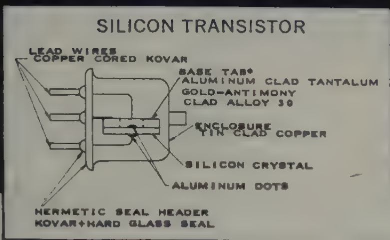

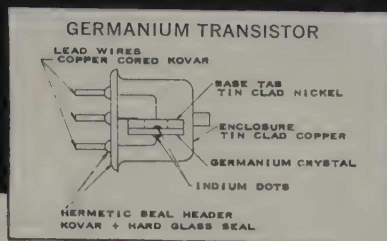

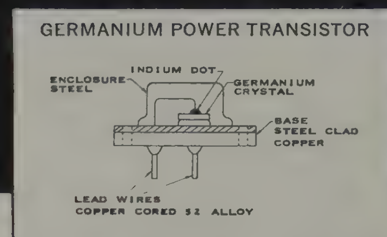

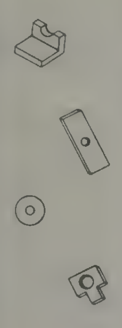

I BASE TAB MATERIAL

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6. 63.2% Lead-35% Tin-1.8% Indium Clad Alloy 30
7. 99% Tin-1% Gallium Clad Nickel
8. 98% Tin-2% Antimony Clad Nickel
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3. 99% Gold-1% Gallium
4. 95% Gold-5% Indium
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6. 99% Gold-1% Aluminum
7. 99% Gold-1% Arsenic
8. Fine Silver
9. 99.5% Silver-.5% Antimony
10. 95% Silver-5% Indium
11. Aluminum
12. High Purity Aluminum

BASE METAL

1. Nickel
2. Alloy 20 (40% Nickel-60% Iron)
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4. Kovar
5. Titanium
6. Tantalum
7. Molybdenum
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III WHISKER WIRE MATERIAL

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2. 99% Gold-1% Gallium
3. 99.5% Gold-.5% Antimony
4. 90% Platinum-10% Iridium

IV BASE MATERIAL

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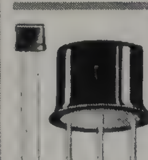
3. Nickel Clad Steel (Nifer)®
4. Nickel Clad Copper
5. Nickel Clad Tantalum
6. Silver Clad Tantalum
7. Aluminum & Nickel Double Clad Tantalum



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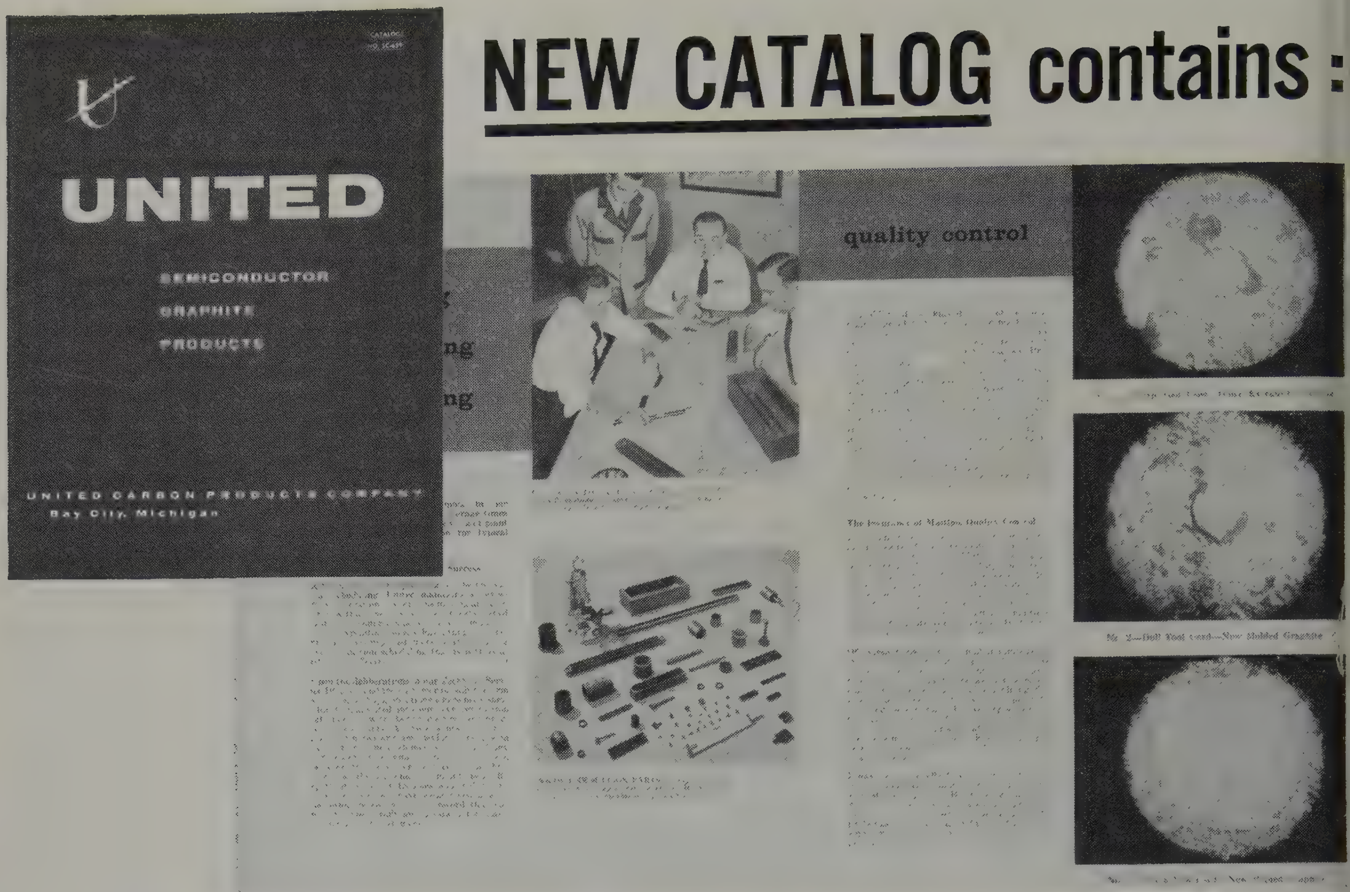

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Semiconductor Diode Switching Characteristics

J. R. MADIGAN AND W. MACDONALD*

The switching characteristics of a semiconductor diode are shown to depend upon properties intrinsic to the diode as well as upon external circuit conditions. In particular, one may adjust external circuit properties in such a way as to make an inherently slow diode appear fast. In addition, one may switch about either the forward or the reverse breakdown points. In switching about the forward breakdown point the current is carried by minority carriers and this produces charge storage effects which limit the speed with which the diode can be switched from its high to its low conductance states. Switching about the reverse breakdown point eliminates the problem of charge storage since the diode current is now carried principally by majority carriers and the switching time therefore tends to be limited by circuit conditions rather than the diode itself.

IN THIS ARTICLE we shall concern ourselves only with diodes which can exist in two stable states, viz., a high conductance or "on" condition and a low conductance or "off" condition. For a semiconductor diode the "off" condition corresponds to operation in the reverse saturation region while the "on" condition may correspond to operation in either the forward bias or reverse breakdown regions of the diode characteristic. In the "off" state the current through the diode is very small and practically independent of voltage over a wide range of bias voltages while in the "on" state for either forward or reverse breakdown the current through the device increases very rapidly with increasing positive or negative bias, respectively. The forward switching characteristic has been discussed rather completely by Kingston[1] and by Lax and Neustadter.[2] Unfortunately, their treatments are restricted to the limiting cases in which the width of the base region, w, is either much greater than or much less than a diffusion length. In diffused junction rectifiers the case where the base region and diffusion length are comparable is common. One would expect the transit time to affect the duration of the switching transient when the diffusion length approaches or exceeds the base width. When this condition is obtained, the carriers disappear both by recombination within the base region and at the ohmic contacts which are, by definition, sinks for minority carriers. This reduces the duration of the recovery phase of the switching transient.[3]

Switching about the reverse breakdown point greatly shortens the switching time.[4] This is due to the fact that the reverse current consists entirely of majority carriers and, therefore, cannot alter the properties of the base layer. Since there is no charge storage in the base region, there is no junction relaxation phenomena associated with reducing the bias voltage below the value necessary to maintain reverse breakdown. For certain logic circuits however, zener switching imposes a limit on the maximum zero to one ratio.

In addition certain logic and coincidence type circuits function as well or better with high conductance diodes than with so called "quick recovery" diodes. It will be shown that the switching speed of a circuit made up of individually slow units is directly dependent upon the forward conductivity of the diode.

Theory

A typical current voltage characteristic of a silicon p-n junction diode is shown in *Fig. 1*. In the forward direction the diode will start to pass considerable current after the voltage reaches about 0.6 volts. In the reverse direction the diode will conduct only a very small current until the voltage reaches a value near V_B, the breakdown voltage. At V_B the current in-

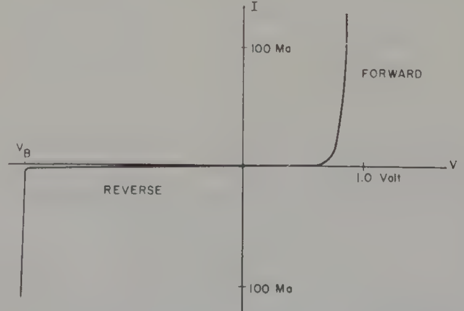

Fig. 1—Typical silicon diode characteristic.

* Hoffman Electronics Corporation, Semiconductor Division, Evanston, Ill.

creases very rapidly and the device is said to go into the breakdown region. This breakdown is not destructive and one can cycle into and out of this breakdown condition indefinitely as long as the unit is kept within the thermal limitations.

For switching purposes one can use either the forward or reverse breakdown regions. In switching about the forward characteristic one can go from the region of high forward conduction to the reverse saturation region. Ideally the diode would instantaneously switch from a forward current, I_f, to the reverse saturation current, $-I_s$, as shown in *Fig. 2-A*. In a real diode, however, the instantaneous reverse current is greater than its saturation value. This large reverse current persists for a time and then decays to the reverse saturation current. *Fig. 2-B* shows a typical reverse switching characteristic for an actual diode. The magnitude of the overshoot in the reverse current and the length of time required for the diode current to decay to its reverse saturation value depend not only upon the characteristics of the diode itself, but also on external circuit parameters.

Switching About the Zero Bias Point, $W >> L$

In forward switching, the current through the diode does not immediately decay to its reverse saturation value because the charge density on either side of the barrier is not that characteristic of a reverse biased junction. While forward bias is applied the current is principally composed of minority carriers and this has the effect of increasing the hole density on the *n*-side and the electron density on the *p*-side of the barrier. These excess minority carrier densities are not distributed uniformly throughout the *n*- and *p*-regions but have their greatest value at the junction and decay to zero as we proceed in either direction from the junction into the bulk material. That is, the total minority carrier densities within the *n*- and *p*-regions approach their thermal equilibrium values at distances from the junction that are large compared to the minority carrier diffusion lengths. Under reverse bias conditions the minority carrier densities in the vicinity of the junction are less than their thermal equilibrium values and approach the equilibrium concentrations as we proceed away from the junction. The width of the region for which the minority carrier densities are less than their thermal equilibrium values (*i.e.*, the width of the space charge or barrier layer) increases with increasing reverse bias. Therefore, in switching from forward to reverse bias conditions the minority carrier densities must first be reduced to their equilibrium values and then the space charge layer established by further reducing the minority carrier density throughout a region whose extent is determined by the magnitude of the reverse bias voltage.

During the initial, or recovery phase, of the switching transient, while the excess minority carrier densities stored within the *n*- and *p*-regions are decaying to their thermal equilibrium values, the reverse current is constant, and is given by the ratio of the reverse bias voltage to the series resistance, *i.e.*, $I_r = V_b/R$. The time during which the space charge layer is established is known as the decay time and the current decays from its constant value of the recovery phase to the reverse saturation current during this period. This behavior is illustrated in *Fig. 3*. Both the magnitude and duration of the constant current phase of the switching transient are dependent on external circuit parameters V_b and R. The magnitude of the constant current increases with increasing reverse bias and with decreasing series resistance and this in turn decreases the duration of the recovery phase of the switching transient. The relationship between the recovery time and the reverse current during the recovery phase may be shown to be

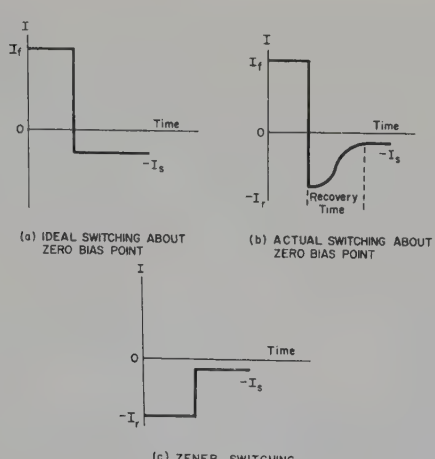

Fig. 2—Typical semiconductor diode switching characteristic.
a—Ideal switching about zero bias point.
b—Actual switching about zero bias point.
c—Zener switching.

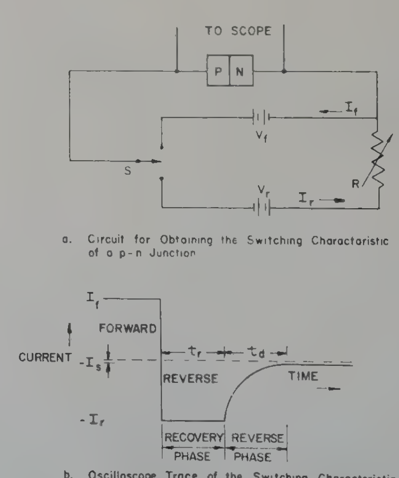

Fig. 3—Switching characteristic of a *p-n* junction about the zero bias point.

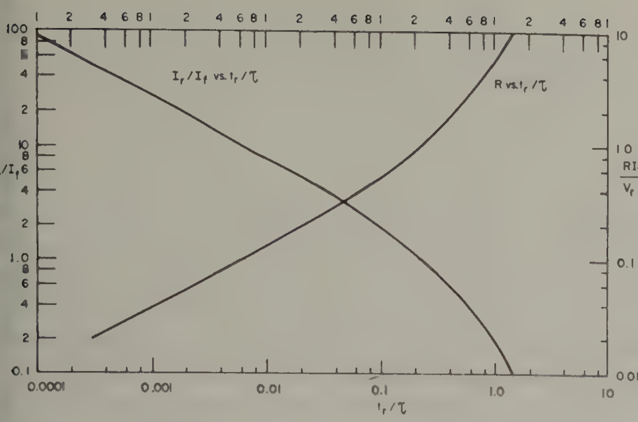

Fig. 4—The dependence of the recovery phase of the switching transient on external circuit parameters.

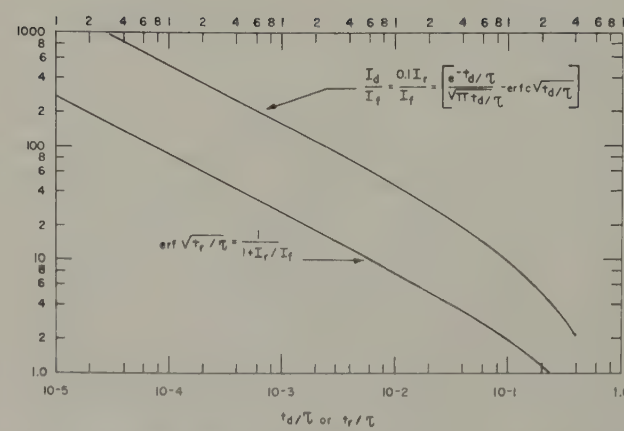

Fig. 5—Comparison of the dependence of the duration of the recovery phase and the decay phase of the switching transient to the ratio of the initial reverse to the forward current.

$$\text{erf}\,\sqrt{t_r/\tau} = 1/(1 + I_r/I_f) \qquad (1)$$

where τ is the minority carrier lifetime. Using this equation the ratio of the recovery time to the lifetime, t_r/τ, is plotted as a function of the ratio of the constant reverse current to the forward current, I_r/I_f, in *Fig. 4*. Since the initial reverse current is equal to the battery voltage divided by the series resistance, t_r/τ is alternatively presented in *Fig. 4* as a function of the series resistance if I_f and V_b are considered to be constant. The duration of the recovery phase of the switching transient for constant mean lifetime τ is seen to increase with decreasing values of I_r/I_f. This result may be explained physically as follows. The current will remain constant and equal to V_b/R only as long as the impedance of the diode is negligible compared to the series resistance. From *Fig. 4* we see that smaller values of I_r/I_f correspond to larger values of the series resistance and thus the diode impedance must reach a higher value before it begins to limit the reverse current. Neglecting the series resistance of the diode itself the impedance depends on the charge stored in the base region and can increase only as fast as this stored charge can be removed. Thus if the diode must reach a higher impedance before it can begin to limit the reverse current, more stored charge must be removed and the constant current or recovery phase will last longer.

An approximate expression for the current during the decay phase of the switching transient is

$$\frac{I_d}{I_f} = \frac{1}{\sqrt{\pi}}\,\frac{e^{-t/\tau}}{\sqrt{t/\tau}} - \text{erfc}\,\sqrt{t/\tau} \qquad (2)$$

where the time is measured from the end of the constant current phase, *i.e.*, from t_r. In the literature, what is referred to as the "recovery time" is the sum of the time corresponding to the constant current phase plus a portion of the decay phase. One usually "recovers" to some specified impedance in the reverse direction and the corresponding decay current is given by the ratio of the reverse bias voltage to the specified impedance. For example one might want to decay to a current equal to one tenth of the initial reverse current. The time, t_d, required for this according to Equation (2), is

$$\frac{I_r}{I_f} = 10\left(\frac{e^{-t_d/\tau}}{\sqrt{\pi}\,\sqrt{t_d/\tau}} - \text{erfc}\,\sqrt{t_d/\tau}\right).$$

This expression is plotted in *Fig. 5* as a function of I_r/I_f. The time to switch from a forward current, I_f, to 0.1 I_r for any given value of I_r/I_f is the sum of values given by *Figs. 4* and *5* times the lifetime.

If the duration of the forward pulse is long compared with the minority carrier lifetime, the base region of the diode will store a quantity of charge equal to $I_f\tau$. The quantity of charge removed when the diode is switched from forward to reverse bias is the area under the reverse current curve in *Fig. 3*. The ratio of the charge recovered, Q_r to the charge stored, Q_s, is therefore

$$\frac{I_r}{I_f}\frac{t_r}{\tau} + \int_{t_r}^{\infty}\frac{I_d}{I_f}\frac{dt}{\tau} = \frac{Q_r}{Q_s} \qquad (3)$$

The integral may be shown to be equal to

$$\int_{t_r}^{\infty}\frac{I_d}{I_f}\frac{dt}{\tau} = \text{erfc}\,\sqrt{t_r/\tau} - 2\int_{\sqrt{t_r/\tau}}^{\infty} y\,\text{erfc}\,y\,dy \qquad (4)$$

The second term on the right hand side of Equation (4), is a standard form[5] and is given by

$$\int_x^{\infty}\xi\,\text{erfc}\,\xi\,d\,\xi = -I^2\,\text{erfc}\,x + \tfrac{1}{2}\,\text{erfc}\,x$$

where I^2 erfc x is the doubly iterated integral of the complementary error function and has been tabulated by Crank[5]. The ratio of the charge removed to the charge stored is therefore

$$\frac{Q_r}{Q_s} = \frac{I_r}{I_f}\frac{t_r}{\tau} + 2\,I^2\,\text{erfc}\,\sqrt{t_r/\tau} \qquad (5)$$

This expression is plotted in *Fig. 6,* as a function of t_r/τ. The ratio of charge recovered to the charge stored approaches a constant value of one half for small values of t_r/τ and decreases rapidly for values of t_r/τ greater than one. This behavior may be understood as follows. Large values of t_r/τ correspond to large values of series resistance and small values of I_r/I_f (see *Fig. 4*). We thus tend to approach open circuit conditions and practically all of the stored charge must disappear by recombination within the base region. In other words the rate of flow of charge back across the junction (i.e., the reverse current) is so small that most of the stored charge disappears by recombination within the base region and therefore does not contribute to the reverse current. Another way of regarding the limiting case of large values of t_r/τ is that τ, the lifetime, should be an upper limit on the value of the recovery time. This would be the case if all the carriers recombine within the time τ. However, if the excess carriers decay exponentially a small fraction of the stored charge can still be recovered even if the circuit parameters limit the reverse current to a very small value.

The fact that Q_r/Q_s saturates is to be expected since one cannot recover more charge than is stored in the base region during the forward pulse. Small values of t_r/τ correspond to low series resistance (see *Fig. 4*) and hence the initial rate of removal of charge (i.e., the reverse current) is large. One would, therefore, expect to recover more charge as t_r/τ decreases since it does not remain in base region long enough to recombine (i.e., the average time a charge stays in base region is short compared to its lifetime). Under these conditions as t_r/τ approaches zero, the first term on the right hand side of Equation (5), tends to zero, and the second term to a constant value of one half. This is what one would expect physically except perhaps for the fact that one can recover at best only half of the stored charge.

Before leaving the simple case where recovery time is determined only by external circuit parameters and lifetime there is one further effect that should be mentioned. It has been assumed that the *p-n* junction initially presents a very low impedance in comparison to the series resistance of the circuit. Under these conditions the entire reverse bias voltage will appear across the load resistor. However, if the series or spreading resistance of the diode is large, as will be the case for certain alloy structures, there will be a voltage divider effect and the voltage across the load will be given by

$$\frac{R}{Z + R} V_b$$

where Z is the series impedance of the diode. This impedance may be regarded as a series combination of the storage capacitance associated with injection of minority carriers into the base region during forward bias and the series resistance of the diode. It may be shown[6] that at forward bias voltages such that $qV_f \gg kT$ the storage capacitance is directly proportional to the forward current and is given by

$$C_{Stor} = \frac{q}{kT} I_f \tau = \frac{q}{kT} Q_s$$

where τ is the minority carrier lifetime and Q_s is the charge stored in the base region during the forward pulse. If the series resistance of the diode is small, the impedance will be inversely proportional to the storage capacitance. Thus for units in which lifetime is very short as a result of severe thermal quenching or other treatment there will be an appreciable voltage drop across the diode. Provided the series resistance is small the voltage drop across the diode is directly proportional to the minority carrier lifetime and may be a suitable measure of very short lifetimes.

Switching About the Zero Bias Point, $W \leq L$

In the case we have just been treating it was assumed that the width of the base region was large in comparison with the diffusion length of the minority carriers. This condition restricts the recovery time to a function of external circuit parameters and lifetimes and allows us to neglect any transit time effects. If, however, the diffusion length is comparable to or greater than the base width, transit time across the base region will effect the recovery time. The general result is a reduction in the recovery time and if the diffusion length is much greater than the base width, the recovery time approaches the transit time rather than the lifetime as a limiting value.

This case has previously been treated by Steele[7] and by Byczkowski and Madigan[3]. The general result is a series solution which can only be solved by laborious numerical methods except for certain special limiting cases. In the general case of arbitrary base width one must solve the series for t_r/τ as a function of W/L. The series may be expressed in the form

$$\sum_{m=0}^{\infty} \frac{\exp - [(t_r/\tau) + (m+\frac{1}{2})^2 \pi^2 (Dt_r/W^2)]}{1 + (m+\frac{1}{2})^2 \pi^2 L^2/W^2}$$

$$= \frac{1}{(1 + I_r/I_f)} \frac{(W/L) \text{ tank } W/L}{2} \qquad (6)$$

Now W^2/D is the diffusion or transit time, t_t, across the base region[8]. This quantity tends to zero as W tends to zero. Thus, the second term in the exponent is the dominant one and the exponent reduces to $(m+\frac{1}{2})^2\tau^2 \; t_r/t_t$. This approximation thus leads to a dependence of t_r on t_t. Since the transit time vanishes in the limit of very narrow base widths, t_r must vanish also. τ should, however, be independent of base width neglecting surface effects; and, therefore, t_r/τ must tend to zero. We have determined t_r/τ as a function of W/L only for the special case where $I_r/I_f = 1$. For values of $W/L < 3$ the ratio t_r/τ falls off very rapidly indicating a strong dependence of the recovery time on transit time.

Switching About the Reverse Breakdown Point

Operation of silicon junction diodes about their reverse breakdown point permits much faster switching times. This is possible since under reverse bias conditions the current is carried by majority carriers and there are therefore no minority carrier charge storage effects. Any charge storage effects associated with the majority carriers would require a deviation from local space charge neutrality which will be self annihilating. Basically the deviation from local space charge neutrality produces an electric field which restores local neutrality within the dielectric relaxation time[9]. The dielectric relaxation time is directly proportional to the base layer resistivity and for any physically attainable resistivities in silicon is not greater than about 10^{-10} sec. It is thus possible in switching about the reverse or avalanche breakdown point to pass very fast pulses without distortion from recovery time phenomena.[10] The switching characteristic would then correspond to *Fig. 2C.*

The nature of the reverse breakdown phenomena imposes certain limits on some switching applications. For example, consider the two input, reverse breakdown, logical *"and"* circuit of *Fig.* 7. Without the application of either positive input pulse, both diodes are normally conducting in their avalanche breakdown regions. The voltage drop between the output, "A · B," and ground is essentially equal to the "zener" voltage of the diodes. With the application of either one of the input pulses, the diode corresponding to that input is switched from the avalanche breakdown region to the low conductance region. Since one leg of the parallel circuit to ground is now (for all practical purposes) open, the the impedance between output and ground is now increased. This results in a voltage output at "A · B" which persists for the duration of the input pulse. Upon simultaneous application of both positive input pulses to the circuit, both diodes are switched from their avalanche breakdown regions to their low conductance regions and a positive pulse approximately equal to E_B appears.

We shall now show that the ratio of the output voltage when both pulses are applied simultaneously to that when only one pulse is applied, i.e., the two to one ratio, is limited by the nature of the "zener" characteristic. If the diodes are initially conducting in their reverse breakdown regions, the maximum pulse that can be applied to turn them off is their reverse breakdown voltage. Any greater signal will drive them into the forward conduction region and lead to charge storage effects. Since in their low conductance state essentially the entire E_B appears across the diodes, E_B must not be great enough to drive the diodes into their reverse breakdown regions. When the signal voltage is applied to *A* and *B* simultaneously, the drop across either diode is the supply voltage minus the signal voltage. Because of the limitation on signal voltage the maximum possible supply voltage is twice the reverse breakdown voltage, and

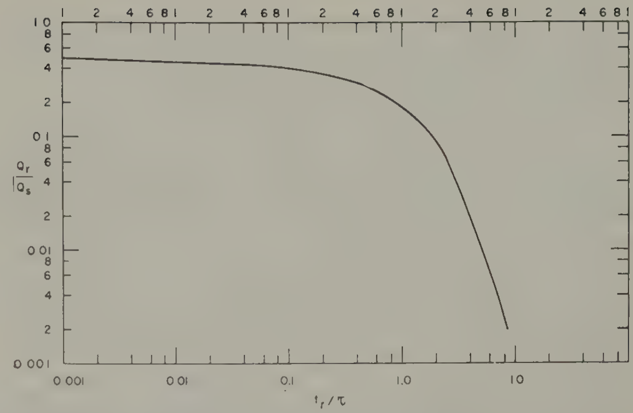

Fig. 6—The ratio of the charge recovered to the charge stored as a function of the ratio of the recovery time to the lifetime.

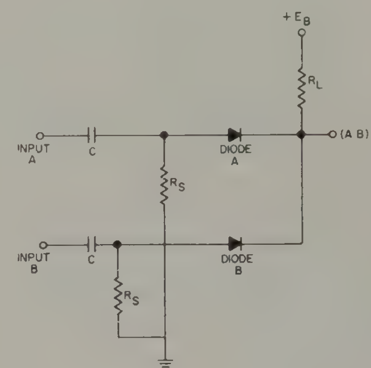

Fig. 7—Schematic diagram of two-input, reverse breakdown, logical "*AND*" circuit.

the maximum output voltage equals the reverse breakdown voltage of the diodes. The voltage pulse that appears when a signal is applied to only one of the inputs, is due to the fact that the impedance between output and ground is now approximately doubled since one leg of the parallel circuit to ground is now effectively opened. The impedance between output and ground is the sum of the reverse breakdown impedance of one of the diodes plus the series resistance, R_s. The size of the output pulse when only one input signal is applied depends on the ratio of the above impedance to R_L. The maximum two to one ratio is obtained by keeping the impedance in the high conductance condition between ground and output as low as possible. There is a practical limitation on R_s, however, since the smaller it is the more power is required in the input pulse to switch the diode from its high to low conductance state. To minimize the reverse breakdown impedance of the diode one should employ a diffused junction device. In alloy units one must use higher resistivity base material to achieve a given breakdown voltage than with diffused regulators because of the steeper impurity gradient at the junction. Thus, for identical geometries the diffused unit will have a lower series resistance and consequently lower reverse breakdown impedance than

an otherwise equivalent alloy unit. The impedance of the diffused unit may be reduced still further by reducing the thickness of the base layer.

The largest two to one ratio in "zener" switching is thus achieved by using relatively high breakdown voltage, diffused junction, narrow base diodes. Since the impedance of the breakdown region increases with increasing voltage and since it is desirable to keep the supply voltage to a reasonably low value, it is not practical to use diodes with reverse breakdown voltages above about ten volts.

Switching with High Conductance Diodes

A high conductance diode usually has low series resistance and long minority carrier lifetime within the base region. The long minority carrier lifetime promotes conductivity modulation (i.e., the reduction of base layer resistivity by minority carrier injection) and greater storage capacitance. The diode impedance is therefore greatly reduced and the diode is more nearly an ideal short circuit during the initial phase of the switching transient. It is therefore possible to decrease the switching time by adjusting external circuit parameters such as the load resistance, without having the impedance of the diode itself as a limiting factor. The suitability of high conductance diodes for certain switching applications is borne out by their successful employment for a number of years in nuclear counting circuits.

Summary and Conclusions

This discussion has confined itself to diodes which can switch from a high to a low conductance state without passing through a negative resistance region. For such units it is possible to predict how the switching transient will depend upon properties of the diode itself and upon the external circuit parameters. In particular it has been shown that an intrinsically slow diode may be made to appear fast by properly adjusting the external circuit parameters. In switching about the zero bias point the charge stored in base region during forward bias is removed partly by recombination within the base, partly by flowing back across the junction, and partly by diffusion to the ohmic contact to the base region. By properly designing the unit one can combine the above decay mechanisms in such a way as to produce a fast switching diode which still has desirable characteristics as a normal diode.

Switching about the reverse breakdown point eliminates the problem of charge storage since the reverse current consists of the flow of majority carriers. Any charge storage effects set up self annihilating electrical fields which restore equilibrium within the dielectric relaxation time. The switching time therefore tends to be limited by circuit conditions rather than the diode itself.

Acknowledgements

We should like to thank the several members of the device development group at Hoffman who read this manuscript. Helpful discussions with L. J. Rose and R. L. White are appreciated.

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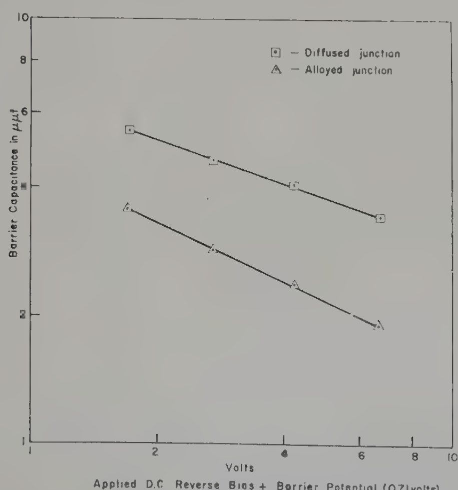

Fig. 6—Capacitance as a function of bias voltage for typical diffused alloy junction silicon diodes.

Errata

The accompanying illustrations are corrected versions of those which appeared in the article "Variable Capacitance Diffused Junction Diodes," Semiconductor Products, Nov. 1959.

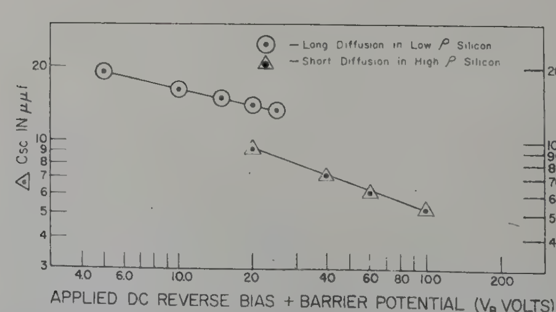

Fig. 7—Dependence of capacitance on bias voltage for two limiting diffusion programs.

Comparative Performance of Saturating and Current-Clamped High Frequency Pulse Circuits

V. P. MATHIS* H. RAILLARD* J. J. SURAN*

The relative performance of saturating and current-clamped flip-flops are compared with regard to such properties as stability, loading capability, pulse repetition frequency, trigger energy requirement and pulse propagation time. It is shown both theoretically and experimentally that the two-terminal driving-point resistance characteristics of the saturating and current-clamped circuits are virtually identical and hence the static properties, e.g., stability and loading capability, are the same for most practical purposes. The saturating circuit has a small advantage insofar as its collector-to-emitter voltage drop, when conducting, is approximately one-half volt less than for the clamped circuit, and consequently the saturating circuit may be loaded a little more. The clamped circuit is advantageous in dynamic performance only when the minority-carrier storage factor of the clamping diode is less than the storage factor of the transistor. Using clamping diodes of the S347G and S555G types, the clamped circuit is definitely superior in dynamic performance to the saturating circuit when transistors of the 2N428 class are used. However, the clamped circuit shows little or no advantages when the 2N501 transistor is employed.

One of the principal characteristics which makes the transistor a highly desirable switching element is its low collector-to-emitter voltage drop when driven into a fully-conducting state. This saturation property of the transistor makes it possible to operate switching circuits at very high efficiencies, compared to electron-tube equivalents, and allows transistors to perform clamping functions as well as amplification in logic circuits.[1] However, the minority carrier storage effects associated with saturation lead to several undesirable effects in the transient-response characteristics of transistor switching circuits and these are generally assumed to result in considerable degradation of switching speed.[2] Consequently, extensive effort has been expended in devising transistor switching circuits which do not saturate. The most successful circuit thus devised consists of a clamping configuration which tends to preserve the high-efficiency property of the transistor switch while maintaining enough collector-to-emitter voltage to prevent transistor saturation.[3] Since all such diode clamping circuits transfer the carrier storage effects from the transistor to the diode, it must naturally be assumed that the diode is considerably "faster" than the transistor.

Non-saturating transistor circuits which employ diode clamps, particularly of the high-efficiency current-clamping configuration described in reference 3, are considerably more expensive than unclamped saturating circuits. For example, in a decade counter having a capacity of five digits, eighty additional diodes are required if current-clamped flip-flops are used in place of saturating flip-flops. It is important for circuit designers, therefore, to know under what conditions non-saturating circuits should be resorted to in place of saturating circuits. The principal object of this article is to provide both theoretical and experimental information which will allow a circuit designer to make a choice between saturating and non-saturating circuits.

At the outset of a study of this type the following questions arise:

1. What transistor types should be considered?
2. What type of circuit configuration should be investigated?
3. What circuit and transistor properties should be investigated?

In view of the desire for high speed in most applications it was decided that only those transistors classified as switching devices and having a minimum gain-bandwidth product of 10 *mc* should be considered. Furthermore, in view of the general trend to diffusion-type transistors it was decided that at least one such type should be included in the study. Consequently, the germanium alloy type 2N428 and the germanium surface barrier diffused type 2N501 were selected as the medium and high frequency transistors, respectively, for use in the circuit and device studies reported below.

The circuit chosen as both sufficiently general and practical to represent saturating transistor pulse circuits is the Eccles-Jordan flip-flop configuration shown in *Fig. 1*. The circuit includes pulse transmission gates of the type used in series and parallel registers. It is designed for logic driving applications and the logic loads are simulated by the loading resistors R_{LX}, each in series with a logic diode which is returned to a

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battery supply. The non-saturating flip-flop is composed of the basic clamped stage shown in *Fig. 2*. Any excess base current above the amount needed for turning on the transistor is effectively bypassed through the germanium clamp diode. The storage properties of this diode will therefore be of interest.

Circuit characteristics of interest include bias stability, loading capability, trigger requirements, maximum frequency of operation and propagation delay. Both bias stability and loading capability are static characteristics of the circuit determined by resistor values and the low-frequency parameters of the transistors. Trigger requirements and speed, on the other hand, are dynamic properties determined by the *RC* time constants of the external networks and the high frequency transistor parameters.

A complete description of the static properties of each of the two circuits can be obtained by finding the driving point characteristic after cutting the circuit at any arbitrary point, for example as in *Fig. 3*. The characteristic is obtained by looking into the emitter of transistor T_1. The type of curve obtained from such a measurement can be calculated and is shown in *Fig. 4*. If T_1 is initially cut off the operating point is at point "1," representing one of the stable states of the flip-flop. At point "P" transistor T_1 becomes conducting and emitter current begins to flow. Point "P[1]" denotes the condition where transistor T_2 also becomes active resulting in a negative slope due to the positive feedback in the flip-flop. The negative resistance region is terminated by either one of two actions:

1. T_2 cuts off before T_1 saturates resulting in the characteristic illustrated on the left-hand side of *Fig. 4*.
2. T_1 saturates before T_2 cuts off, resulting in the second characteristic illustrated in *Fig. 4*.

An analysis of the curves shows that the static characteristic is essentially the same for both clamped and unclamped circuits and may be made identical with small changes in resistance values. The calculated curves were verified experimentally with excellent agreement. It is therefore concluded that no significant advantage in static performance is obtained by clamping.

The principal interest is then directed towards the following dynamic properties of the circuits:

1. Trigger requirements.
2. Maximum pulse repetition frequency.
3. Pulse propagation speed.

Since the static characteristics of both saturating and non-saturating flip-flops are approximately the same, the threshold current and voltage trigger levels must be identical. Consequently, the only difference must lie in the time required for triggering. This factor can be accounted for by considering the trigger charge. Table I shows the equations derived for the trigger charge Q_T for both the saturating and non-

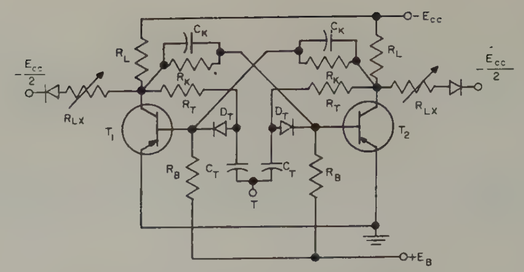

Fig. 1—Saturating flip-flop.

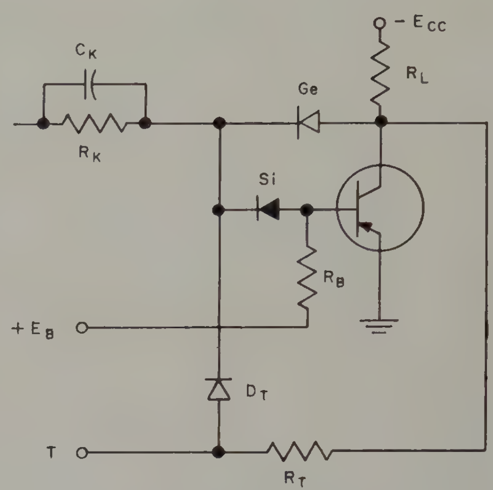

Fig. 2—Current clamp.

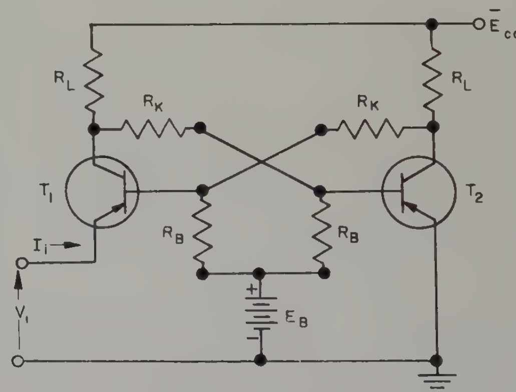

Fig. 3—Circuit for measuring driving-point characteristic.

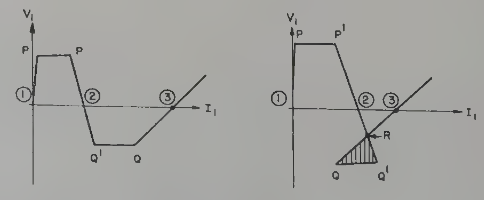

Fig. 4—Driving-point resistance characteristics.

saturating circuits. The parameters of Table I are defined as follows:

- I_C — Collector current of conducting transistor
- α_E — Common emitter current amplification
- $\omega_{\alpha E}$ — Cutoff frequency of α_E
- ΔV_c — Collector voltage swing
- E_{cc}, E_B — Battery voltages; as in *Fig. 1*
- V_{BE} — Base-emitter voltage of conducting transistor
- V_S — Voltage drop of silicon diode
- C_c — Collector capacitance
- C_L — Load capacitance
- R_L, R_K, R_B — Circuit resistance values, as in *Fig. 1*
- K_S — Minority carrier storage factor of transistor
- K_{SD} — Minority carrier storage factor of diode

The trigger charge consists of two terms, namely, the charge necessary to cause reliable regeneration in the flip-flop Q_R, and the charge necessary to remove the excess minority-carriers from the transistor Q_S (saturating case) or the diode Q_D (non-saturating case). It is seen in Table I that the only difference in the trigger charge for the two cases is in the minority carrier storage factor of the transistor, K_S, and the diode, K_{SD}. The diode clamp is therefore of advantage with respect to trigger requirements only if the minority carrier storage time of the diode is significantly less than that of the transistor.

To support this conclusion a number of experiments were carried out. *Fig. 5* shows the minimum trigger charge as a function of the load current I_C, calculated and measured, for both the saturating and the clamped flip-flops using 2N428 transistors. Each flip-flop has two transistors and the calculations result therefore in a pessimistic curve based on the measured high-frequency parameters of the poorer transistor (No. 51) and one for the better transistor (No. 11). In the clamped version no significant difference is found using different transistors of the same type, because storage effects are due to the diode clamps rather than the transistors. It is seen that the experimentally measured trigger charge values lie in the expected regions, thus supporting the validity of the calculated values. It is also apparent that the saturating circuit requires from 3 to 7 times as much trigger energy as the clamped circuit, because the transistor saturation charge is an order of magnitude higher than the diode charge.

Fig. 6 shows a similar set of curves using the higher frequency 2N501 transistors. It is noted that the trigger charge requirements are an order of magnitude less than for the 2N428 transistors. Using the transistor pair No. 7 and 8, virtually no difference in trigger charge exists between clamped and unclamped circuits while for the pair No. 75 and 76, a reduction of trigger charge by about 2:1 is obtained because transistors No. 75 and 76 have a lower gain-bandwidth product than transistors No. 7 and 8. Again a good correspondence between calculations and measurements is found.

An interesting phenomenon is the effect of collector and load capacitance on trigger charge. Due to these capacitances, the necessary charge to cause regeneration is effectively increased, particularly for high frequency transistors. Table II shows a tabula-

Table I Equations for trigger change for saturating and non-saturating circuits.

NON-SATURATING FLIP-FLOP:

$$Q_{TN} = Q_R + Q_C = \left[\left(\frac{I_C}{\alpha_E \omega_{\alpha E}}\right) + (\Delta V_C)\left(C_C + \frac{C_L}{\alpha_E}\right)\right]$$

$$+ K_{SD}\left[\frac{E_{CC} - (V_{BE} + V_S)}{R_L + R_K} - \frac{E_B + V_{BE}}{R_B} - \frac{I_C}{\alpha_E}\right]$$

SATURATING FLIP-FLOP:

$$Q_{TS} = Q_R + Q_S = \left[\left(\frac{I_C}{\alpha_E \omega_{\alpha E}}\right) + (\Delta V_C)\left(C_C + \frac{C_L}{\alpha_E}\right)\right]$$

$$+ K_S\left(\frac{E_{CC} - V_{BE}}{R_L + R_K} - \frac{E_B + V_{BE}}{R_B} - \frac{I_C}{\alpha_E}\right)$$

Table II N_c and C_c *vs.* gain-bandwidth product.

$$Q_R = \left(\frac{I_C}{\alpha_E \omega_{\alpha E}}\right)(1 + N_C)$$

$\alpha_E \omega_{\alpha E}$	C_C	TRANSISTOR TYPE	N_C
8×10^6	40×10^{-12}	2N43	0.32
55×10^6	3×10^{-12}	2N167	0.17
100×10^6	10×10^{-12}	2N428	1.0
500×10^6	2×10^{-12}	2N501	1.0

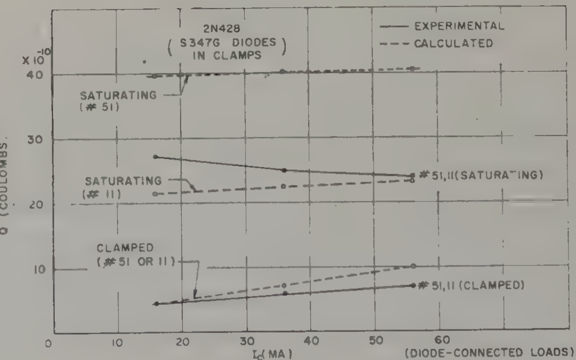

Fig. 5—Minimum trigger charge (2N428).

tion of N_C *vs.* transistor gain-bandwidth product for several transistor types, where N_C is that portion of the regenerative charge Q_R due to collector and load capacitance. N_C is calculated assuming a load resistor of 1000 ohms and assuming that the load capacitance portion, C_L/α_E, is negligible compared to the collector capacitance C_C. Apparently collector capacitance has a significant effect on regenerative charge Q_R in that Q_R is doubled for the 2N428 and 2N501 transistors. The only way to reduce this term is by reducing the collector voltage swing. However for high gain-bandwidth transistors it may be desirable to reduce the trigger sensitivity to prevent noise triggering. This can be achieved by adding load capacity.

The inherent maximum frequency of operation is not affected by transistor saturation. If the trigger charge is greater for the saturating flip-flop, however, more charge must be coupled in and hence the time constant of the trigger network may limit the frequency. *Fig.* 7 shows curves of trigger voltage versus pulse repetition frequency. The trigger capacitor is adjusted so that the flip-flop just triggers reliably with a 4 volt trigger pulse at low frequencies. Using 2N428 transistors, more trigger charge is required in the saturating than in the clamped circuit resulting in higher trigger capacitors and hence a larger time constant of the trigger network. This in turn causes a poorer frequency response at high frequencies. The 90% recovery breakpoint of the trigger network occurs at 300 *kc* for the unclamped and at 800 *kc* for the clamped circuit. For the 2N501 transistor, the trigger charge is so small in either case that the frequency response is limited by the discharge time constant of the flip-flop cross-coupling network. Thus, for both the saturating and the clamped circuit, the frequency response curves are identical. The maximum frequency is somewhat higher for the 2N501 circuit since the cross-coupling capacitor values were smaller than those for the 2N428 circuit.

Next a comparison of signal propagation times is considered. Pulse propagation time is defined as the time required to transmit a pulse from input to output and is the signal delay introduced by the flip-flop in a logic circuit. In a serial counter, for example, the average propagation time per stage is the total delay divided by the number of counter stages. The expected propagation time is the time required to pass the trigger charge, Q_T, from one state to another. Table III shows the equations for the current i_T generated by a square pulse from a voltage generator of magnitude E_T through a capacitor C_T into a circuit with a total series resistance R_S and the time t_D required to pass the charge Q_T through the capacitor. In a serial counter, E_T is approximately the collector voltage swing of the flip-flop and R_S is the sum of the base spreading resistance r_b' and the impedance looking into the collector of the driving stage. In a saturating flip-flop, this impedance is the collector saturation resistance which is usually very small compared with r_b'. In a clamped flip-flop, the resistance seen at the collector is approximately the sum of the clamping and reference diodes plus the base-spreading resistance of the transistor. Hence, for a saturating flip-flop, $R_S \approx r_b'$ while for a clamped flip-flop, $R_S \approx 2r_b'$ (neglecting the clamp and reference diode resistances). Thus it appears that the advantage of the clamp must be strong enough to reduce the trigger charge by a factor greater than two if any advantage

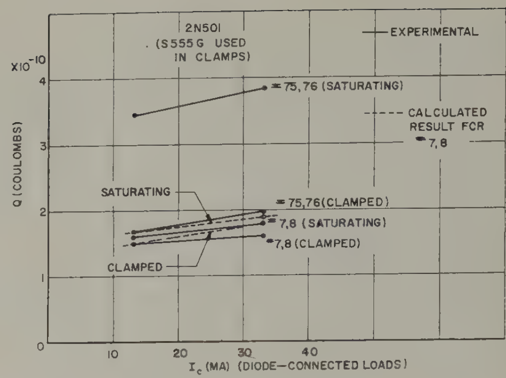

Fig. 6—Minimum trigger charge (2N501).

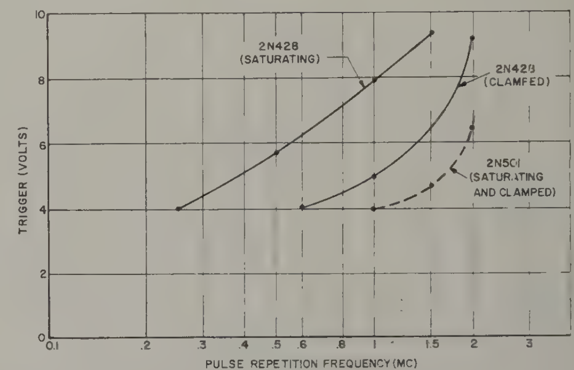

Fig. 7—Trigger voltage *vs.* pulse repetition frequency.

Table III—Current Equations.

TRIGGER CURRENT:

$$i_T = \frac{E_T}{R_S} e^{-t/R_S C_T}$$

DELAY TIME:

$$t_D = R_S C_T \ln\left[\frac{1}{1-(Q_T/E_T C_T)}\right]$$

Table IV—Summary of Average Experimental Results.

DYNAMIC CIRCUIT PROPERTY	2N428		2N501	
	SATURATING	CLAMPED	SATURATING	CLAMPED
TRIGGER CHARGE (CMBS.)	30×10^{-10}	7×10^{-10}	2.5×10^{-10}	1.8×10^{-10}
PROPAGATION TIME (mμSEC.)	170	100	12	17
REPETITION RATE (5V. TRIGGER)	350 KC**	1 MC*	1.7 MC*	1.7 MC*

* LIMITED BY FLIP-FLOP COUPLING-NETWORK TIME CONSTANT.

** LIMITED BY TRIGGER-NETWORK TIME CONSTANT.

is to be gained in propagation time by using clamped stages instead of saturating stages.

For experimental verification the delay through a five stage serial counter was measured. The counter is loaded by a logic load, as shown in *Fig. 8,* with a variable load current. *Fig. 9* shows the measured delay per stage as a function of load current using 2N428 transistors. As was found earlier, clamping resulted in a large reduction of trigger charge and hence clamping reduces the delay time by approximately 2:1. For the 2N501 transistor, essentially no advantage in trigger charge was found to exist. Consequently, the smaller collector resistance of the saturated transistor should reduce the delay time in the saturated flip-flop below the value in the clamped flip-flop. This expectation is confirmed in the curves of *Fig. 10* where the propagation delay per stage using 2N501 transistors is shown.

It is therefore concluded that clamping results in an improvement of pulse propagation only if the clamp reduces the necessary trigger charge by a factor of at least 2:1.

Conclusions

In conclusion, the relative performances of saturating and current-clamped (or Baker-clamp) flip-flops have been compared with regard to such properties as stability, loading capability, pulse repetition frequency, trigger energy requirement and pulse propagation time. It is shown both theoretically and experimentally that the two-terminal driving point resistance characteristics of the saturating and current-clamped circuits are virtually identical and hence the static properties, e.g., stability and loading capability, are the same for most practical purposes. The saturat-

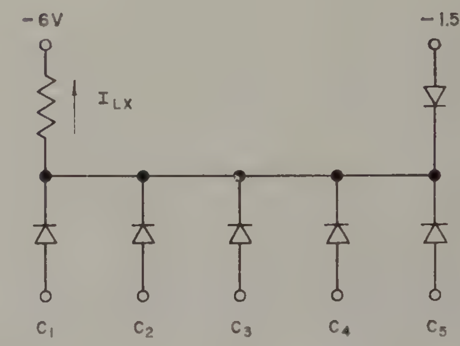

Fig. 8—Counter loading circuit.

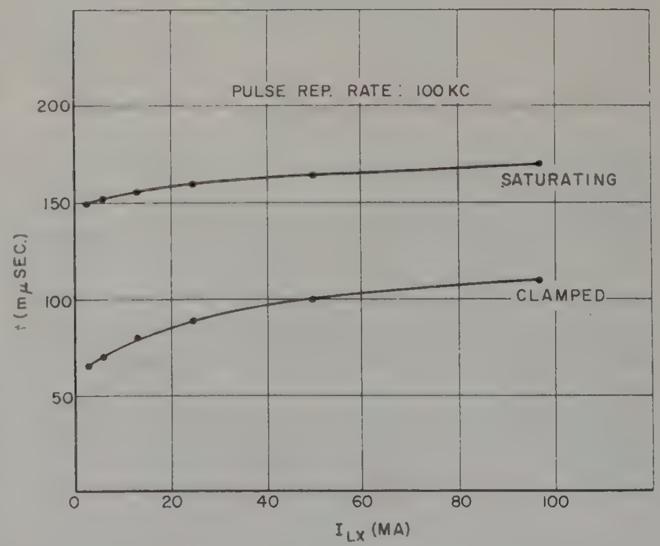

Fig. 9—Propagation time per stage (2N428).

ing circuit has a small advantage insofar as its collector-to-emitter voltage drop, when conducting, is approximately one-half volt less than for the clamped circuit, and consequently the saturating circuit may be loaded a little more.

The clamped circuit is advantageous in dynamic performance only when the minority-carrier storage factor of the clamping diode is less than the storage factor of the transistor. Using clamping diodes of the S347G and S555G types, the clamped circuit was definitely superior in dynamic performance to the saturating circuit when transistors of the 2N428 class were used. However, the clamped circuit showed little or no advantages when the 2N501 transistor was employed. The average experimental results obtained for the logic driving flip-flops discussed are summarized in Table IV.

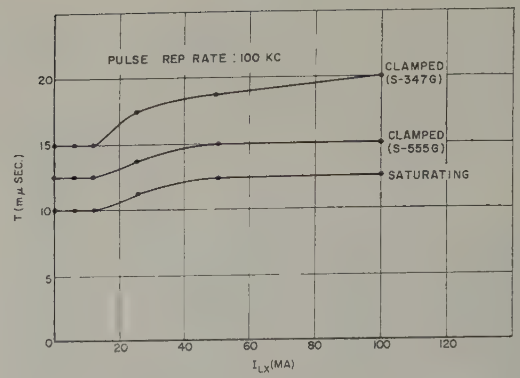

Fig. 10—Propagation time per stage (2N501).

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A New Technique For Computer Switching

CARL M. CAMPBELL, JR.*

Many solid-state computer switching techniques have been devised, each better than the others for certain set of requirements. A new and rather different switching technique is here presented, which is quite favorable for many applications. First, the operating conditions for which it is intended are described. Then the technique itself is explained. Finally an example is given of its application.

Because of the wide variety of requirements for military computers (size, environment, speed, etc.), many different switching circuitry techniques have come into use, each best suited to a certain combination of factors. This paper deals with a circuitry technique which is quite advantageous under certain conditions. These conditions are small physical size for the overall computer, medium frequency rates (for computation in the 500 *kc* range), operation over a wide temperature range (up to about 80° C.), low cost, and high reliability. These conditions are found in many military applications; for example, aircraft or submarine installations.

The purpose of this paper is to describe how the technique evolved, how it operates, and how it can be applied. The characteristics of the technique, which are applicable to the above conditions, are as follows. First, relatively few components (especially transistors) are required, and all components are common, moderately priced items. This reduces cost and physical size and improves reliability, since there are fewer parts to fail. Second, all transistors are either *off* or saturated; transistor dissipation is always small, meaning that the units can operate at close to their storage temperature. Third, unlike practically all other solid-

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state saturating techniques, transient response does not deteriorate with increased temperature. Thus, the computer can maintain a fairly high frequency over the entire temperature range.

Evolution

This technique evolved from an attempt to determine a minimum-cost, minimum-component switching system from a study of typical computer logic. Normally, only about four levels of gates are used from the output of one flip-flop to the input of the next. In addition, most flip-flops are reset in groups, but set individually through gates. Also, in most cases, only the *one* output of the flip-flop is used. Finally, flip-flops practically always drive *and* gates, though they may be driven from either *and* or *or* gates.

To have a minimum-cost system, it appeared that diodes rather than transistors should be used for gating. In a diode-gating system, the current decreases very rapidly (much more so than voltage) as the signal propagates through successive stages. Therefore, if a simple flip-flop having very high current gain could be developed, transistors which would normally be used purely for amplification purposes could largely be eliminated. Such a flip-flop should have the following characteristics. First, it should have very high current gain (as well as voltage regeneration), especialy from *set* input to *one* output. The current output should be in such a direction as to drive *and* gates. Second, it should use as few components as possible. Actually, the *zero* output could be omitted if component savings would result. Third, all transistors should saturate when *on* to assure low power dissipation; hence, higher ambient operating temperature.

We will now consider the actual circuitry to see how it achieves the above characteristics.

Operation

The flip-flop circuit is shown in *Fig. 1*. Only three transistors, three resistors, and four diodes (one of them a silicon "stabister") are used. The operation of the circuit is as follows. Let us assume that T_2 is *off*. Because of the current path from plus 20 volts through the 2K resistor, the stabistor, and the diode to ground, D_3, the emitter of T_2 will be at approximately ground potential. Because of its high forward drop, the anode of the stabistor will be at approximately plus 0.7 volts. If we further assume that both the *set* and the *reset* terminals are in the *zero* state (minus 6 volts on the former, and minus 3 volts on the latter), the effect is to cause the conduction of diode D_2, and the conduction and saturation of T_1. If we assume a 0.4-volt drop across the conducting diode, and a 0.2-volt (collector to emitter) drop across the saturated transistor, the base of T_2 will be at plus 0.1 volt with respect to the emitter. Hence, T_2 is held *off* as initially assumed. All that is required for this condition is that the drop across the stabistor equal or

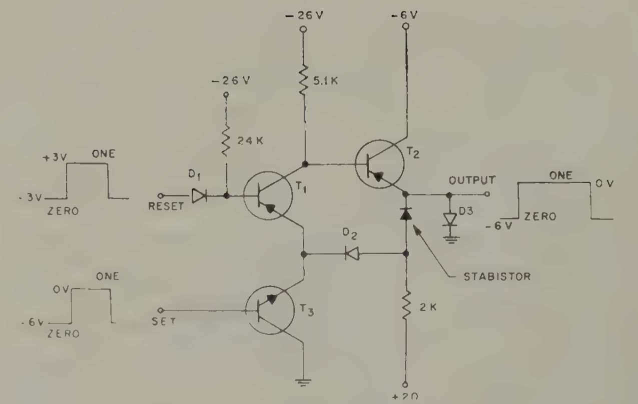

Fig. 1—High gain flip-flop.

exceed the drop across the conducting diode, D_2, and the saturated transistor, T_1. The flip-flop is hence stable, and is in the *one* state.

Now let us assume, under the conditions just described, that the anode of D_1 (*reset* terminal) suddenly rises from minus 3 volts to plus 3 volts, indicating the presence of a *reset* pulse. Since the emitter of T_1 cannot be more positive than about plus 0.5 volt, D_1 will conduct causing T_1 to become back-biased and rapidly turn off. As T_1 turns off, the base of T_2 will go negative, followed by the emitter of T_2, until both junctions reach minus 6 volts, at which point the transistor is saturated. When the emitter of T_2 reaches minus 6 volts, the anode of the stabistor cannot be more positive than about minus 5 volts. Thus, even after the reset pulse goes away, and the reset terminal returns to its normal level of minus 3 volts, there is no way for D_2 and T_1 to begin conduction because of this 2-volt back bias. The flip-flop is now stable in the *zero* state, which corresponds to an output voltage of minus 6 volts. Note that the flip-flop has the ability to draw a very large current from the load under these conditions. This current flows from the load through T_2 to minus 6 volts.

Under the above set of conditions, let us assume that the base of T_3 rises from minus 6 volts to ground, indicating the presence of *set* pulse. This will cause the emitter of T_3, and hence the emitter of T_1, to rise to ground also. Since the anode of D_1 is assumed still at minus 3 volts, ground on the emitter of T_1 will cause it to conduct. T_1 will saturate, thus bringing the base of T_2 to ground. The emitter of T_2 will follow and, when the emitter reaches ground, the anode of the stabistor will be at about plus 0.7 volt. This will cause the conduction of D_2, which will keep T_1 conducting even after the base of T_3 returns to minus 6 volts upon the termination of the set pulse. Thus, the flip-flop has returned to the *one* state where this description began.

From the preceding description, the features of the circuit can be easily seen. It is clear that few components are required for the circuit. All of these components are conventional, moderately priced items.

Furthermore, the stabistor may be replaced by a resistor; however, about a 25 percent decrease in current gain will result. It is also possible to replace T_3 with a diode, although to do so decreases current gain considerably.

Output current is high, with a "worst case" value of 50 milliamperes or greater, depending upon the transistors used. This current is in the direction to drive diode *and* gates, as will be seen later. Input current required at the *set* terminal is approximately 0.5 *ma.*, and at the *reset* input about 1 *ma.* Thus, the current gain from *set* input to output is about 100. Transition time for the circuit is approximately 0.6 microsecond on setting, and 0.2 microsecond on resetting, though the former time can be considerably reduced (down to about 0.15 μs) by increasing the input current at the *set* terminal.

The circuit has the capability to be set with a pulse of the same type which it generates, though the reset pulse must be shifted in level. This need for a special *reset* circuit to shift the level (in the simplest case it need be only a capacitor) is not serious, as it is common to reset many flip-flops together, so one *reset* circuit can suffice for many. Good noise insensitivity and good voltage regeneration are further features of the circuit. When a *set* pulse is applied, it need only be more positive than minus 3 volts to cause the switching of T_1 and hence of the flip-flop. However, if it is not more positive than minus 3 volts the flip-flop will remain unchanged. Thus, the circuit considers any level on the *set* input below this reference level as a *zero* and any level above the reference as a *one*. Thus, the input signal can become very deteriorated and still properly control the flip-flop. The output is the full 6 volt swing under all conditions. It should also be noted that during the simultaneous presence of a *set* and a *reset* pulse, the circuit will always be in the *zero* state. This capability of being able to "inhibit" the flip-flop by a reset pulse is often logically useful.

As has been pointed out, transistors are saturated while *on*. This means low dissipation. In most saturating circuits, the turn-off time of the transistor increases with temperature and causes a decrease in transient response. This is not so in the case of this circuit. All transistors when *on* are turned *off* by a large reverse base current pulse, so that turn-on time, rather than hole storage time, is the main factor governing transition speed. Since turn-on time does not increase at higher temperatures, neither does the transition time of the circuit as a whole.

The flip-flop just described is especially designed to drive diode gates. *Fig. 2* shows a typical diode *and* gate and a diode *or* gate suitable for use in this system. By a proper choice of resistors, a gate can drive *and* gates, *or* gates, and flip-flops. The flip-flop can drive *and* gates directly, since this type of gate requires a driving circuit which pulls current from it. The flip-flop can be made to drive *or* gates with the addition of a resistor, although this necessity seldom arises.

Thus far the operation and features of the circuit have been described. Next, applications of the circuit will be considered.

Applications

The principle of a high-current-gain flip-flop driving diode gates is quite applicable to computer logic in general. However, it is especially well suited for use in registers, which is where the majority of flip-flops are generally used in a computing system. In an ordinary type storage register, all stages can be simultaneously reset, and the new information gated in. Thus, only one reset circuit is needed for the entire register. Since registers usually drive many gates, the high-current output of the flip-flop and its relatively few parts make it ideal for this type of application.

The technique is also very well suited for shift-register applications. A special shifting technique has been devised which takes advantage of the characteristics of the flip-flop. This is indicated logically in *Fig. 3* and electrically in *Fig. 4*. Each stage of the shift-register is composed of two flip-flops and two *and* gates. The two flip-flops in any vertical line are both for the same stage. During any given time interval between shift pulses, one flip-flop of the pair is transmitting to the next stage, while the other is receiving from the preceding stage. The next shift pulse serves to reverse this situation; that flip-flop which had been receiving from the preceding stage now transmits to the next, whereas that flip-flop of the pair which had been transmitting to the next stage now receives from the preceding. Because any stage has the capability of simultaneously transmitting and receiving information, the information has actually been shifted prior to the shift command, and so can be read out almost immediately after the shift command has been received. If parallel outputs are required after every shift pulse, the *or* gates indicated by dotted lines must be included. If parallel outputs are required only occasionally, they may be taken directly from either the upper or the lower line of flip-flops as indicated. The pulses which must be generated to actuate the shift-register are also indicated in *Fig. 4*. The amount of logic necessary to generate them is small. Only two *reset* circuits are required for the entire register, one for the upper

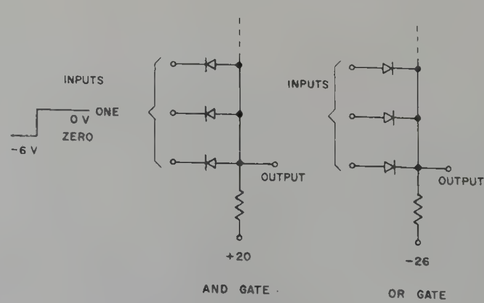

Fig. 2—Typical diode gates.

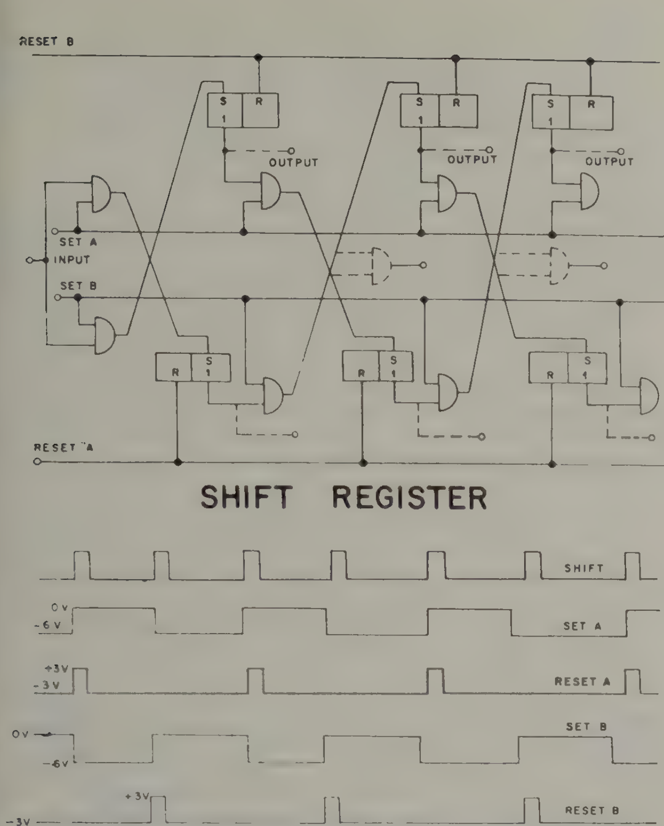

Fig. 3—Shift register and shift register control pulses.

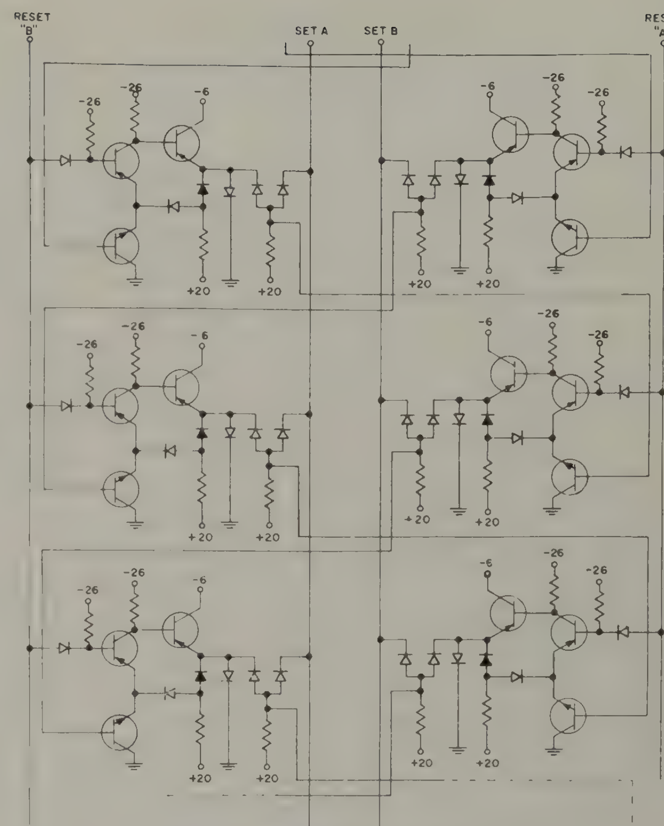

Fig. 4—Shift register circuitry.

line of flip-flops, and one for the lower. The circuit schematic (*Fig. 4*) of the shift-register shows that there are no reactive elements at all used in the register. It is felt that the elimination of these reactive elements makes a more reliable system from the point of view of transient errors than would otherwise result.

Conclusions

No one circuitry technique is ideally suited to all situations. Where it is required to have a system with as few components as possible, with good transient response over a wide temperature range and at a low cost, the technique of using a high-current-gain flip-flop with diode gates is quite favorable. The flip-flop presented in this article is well suited for this application. It is especially well suited for use in registers and shift-registers.

Measurement of Switching Transistor Parameters*

R. C. JOHNSTON** R. L. BURKE**

A system of transistor test sets has been developed which combines speed in loading with accuracy in both the d-c and high-frequency tests. The transistors are loaded into a ten-socket cartridge which is then inserted in sequence into the tests. Circuit diagrams are given for eleven test sets, and the mechanical design of the cartridge and test sets is illustrated.

THE TRANSISTOR SECTION OF GROUP 53 (formerly 63) of the Lincoln Laboratory has for the past seven years been engaged in an extensive switching-transistor testing and evaluation program. Under the direction of Dr. D. J. Eckl the section has aided manufacturers in evaluating developmental transistors and has offered suggestions for changing the construction to give better switching characteristics and especially lower hole storage. The primary application of the transistors is in a high-speed, experimental digital computer, so most of the units

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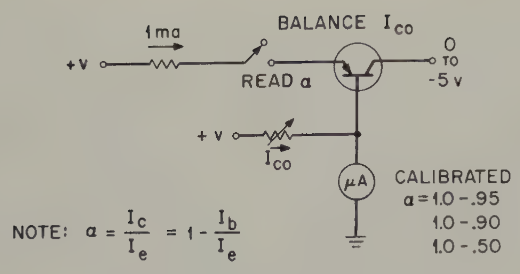


Fig. 1—1 *ma.* α test.

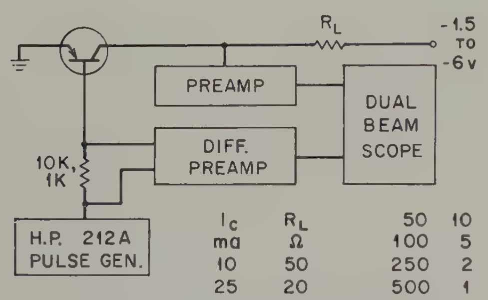


Fig. 2—High current β test.

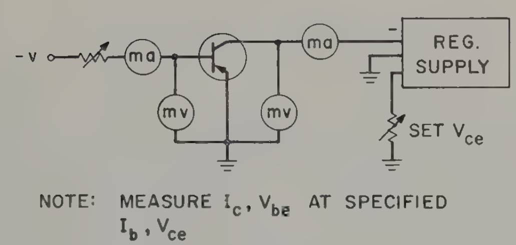


Fig. 3—$I_{c\ sat}$ *test.*

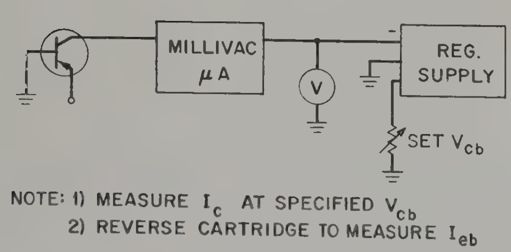


Fig. 4—I_{cb}, I_{eb} test.

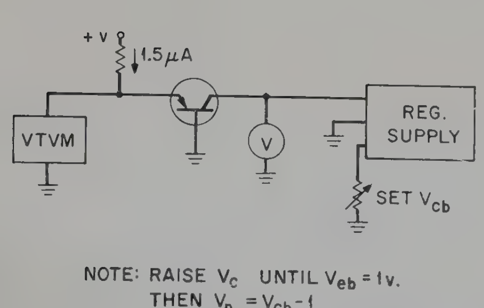


Fig. 5—Punch-through voltage test.

tested are in the 50 *mc.* range and above. However, many transistors go into core and magnetic-film memories, and into drivers for the in-out equipment, so just about the entire frequency and power spectrum of switching transistors is encountered.

The number of transistors received has risen from 255 in 1952 to 50,070 in 1958. The methods of testing were revised almost continuously during this time to improve testing speed, accuracy and sophistication.

The measured data on experimental transistors and on about 10 percent of the transistors received in large quantities is recorded on file cards. The remaining transistors are tested on a *go, no-go* basis. Some units are re-measured after being life tested. The resulting mass of data is placed on punched cards and analyzed by a card machine. The results of this testing and analysis make possible the evaluation of new transistor types and the prediction of operating life of transistors in circuits.

Static Parameters

There are nine static-parameter test sets in use. Briefly they are as follows: 1) d-c α, 2) High-current β (measured pulse-wise), 3) I_c sat (I_c at specified V_{ce} and I_b) and also a measurement of V_{be} under the same conditions, 4) I_{cb} and I_{eb}, 5) Punch-through voltage, 6) Diode breakdown voltages V_{cb} and V_{eb} as well as open-base V_{ce}, 7) Avalanche voltage (open-base V_{ce}) measured at 1 *kc*, 8) A Tektronix 575 curve tracer, and 9) A Librascope graphic curve plotter.

The first four tests are done on practically every transistor while the rest are used as needed. Simplified circuit diagrams are shown in (*Figs. 1-7*). All tests include a *p-n-p, n-p-n* switch which reverses all supply and meter polarities. Extensive use is made of the Electronic Measurements Co. Model 212A, a reasonably priced 100*ma.*, 100*v.* regulated supply which is capable of regulating down to zero volts and of being controlled externally. For instance the $I_{c\ sat}$ test requires a 150 *mv* supply regulated from 0 to 50 *ma.*

Dynamic Parameters

There are five tests used to measure the transient behavior of switching transistors. Briefly they are: 1) τ_s, a storage-time test which measures the time to recover from an operating point very deep into satura-

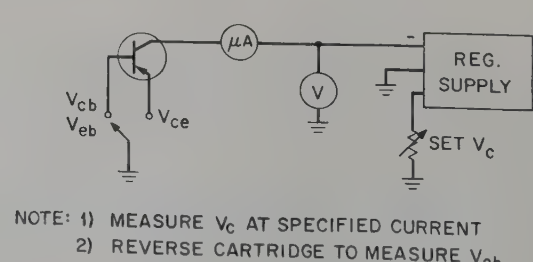


Fig. 6—V_{cb}, V_{eb}, V_{ce} test.

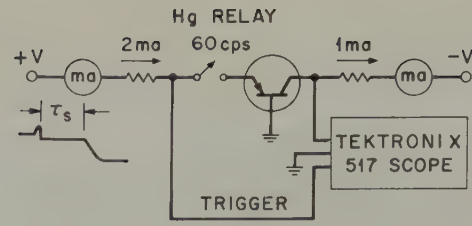
tion, 2) K_s', a storage-time test which measures the charge stored in the base, 3) f_T, or gain-bandwidth, 4) A Tektronix type-R rise-time plug-in unit, and 5) τ_B, an effective baselifetime test (after Giacoletto and Lederhandler[1]).

The first three tests are performed on most transistors while the remaining two are used as needed. Simplified circuit diagrams are shown in (*Figs. 8-11*). The τ_s test is the basic storage-time test. The formula of Ebers and Moll[2] may be used to predict the storage time under conditions of different current drives. This test measures τ_s down to about 10mμ sec. In 1956 the need for a faster production hole-storage test arose, and with the cooperation of the Philco Research Division, the K'_s test was developed. The charge stored in the base is measured by transferring it onto a capacitor and measuring the voltage. The results correlate fairly well with the τ_s test. For more details, refer to a 2N393 specification sheet.

The f_T test measures h_{fe}, the common-emitter current gain. The product of h_{fe} and the frequency of measurement is then f_T as long as the measuring frequency is between the common-emitter and common-base cut-off frequencies. The test may be made by setting the frequency and measuring h_{fe} or vice-versa. The alpha cut-off frequency is not measured in this laboratory because it is difficult to measure accurately, and because the common-emitter rise time depends on f_T and not f_a[3]. f_a equals *1.2* f_T for an ideal, homogeneous-base transistor and as much as twice f_T for some graded-base transistors.

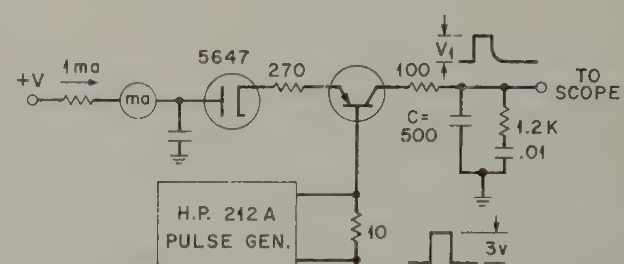
Mechanical Design

In 1956 a multitester was developed that could give 25 transistors seven static tests. The transistors and tests were changed by stepping relays. This method was satisfactory for the static tests, but the long leads prevented its use for the dynamic tests. Much testing time was consumed placing the transistors in the sockets of the individual tests. The solution to the problem was a *10*-transistor cartridge which could be used in the individual tests. Short leads are maintained, and the transistors have to be placed in sockets only once. The cartridge, shown in (*Fig. 12*), consists of 17-gauge, hollow-needle stock molded in epoxy. The



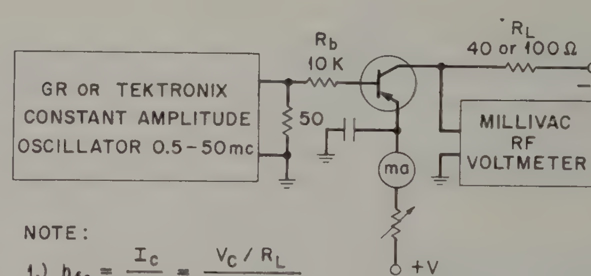
NOTE:
SET CURRENTS WITH RELAY CLOSED.

Fig. 8—τ_s test.



NOTE:
$K_s' = \frac{CV_1}{I_b} = 500\ V_1 \frac{\mu\mu coul}{ma}$ or mμsec.

Fig. 9—K_s test.



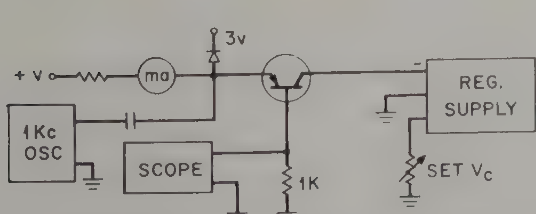
NOTE:

1.) $h_{fe} = \frac{I_c}{I_b} = \frac{V_c / R_L}{0.5 / 10K}$

2.) $f_T = f h_{fe}$

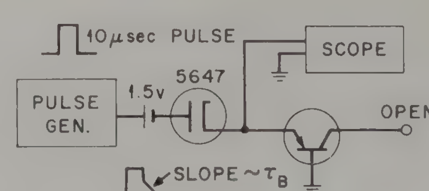
3.) R_b AND R_L ARE HIGH FREQUENCY RESISTORS.

Fig. 10—f_T test.



NOTE: RAISE V_c UNTIL PHASE OF V_b REVERSES INDICATING $\alpha = 1.0$

Fig. 7—Avalanche voltage test.



NOTE:
ADJUST PULSE AMPLITUDE FOR FLAT TOP ON OUTPUT PULSE.

Fig. 11—τ_B test.

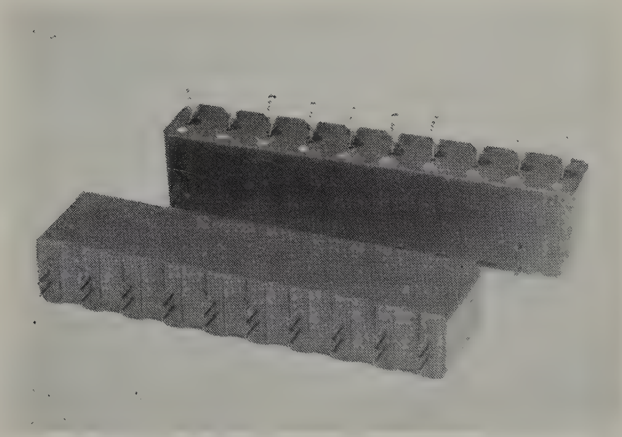


Fig. 12—10 transistor cartridge.

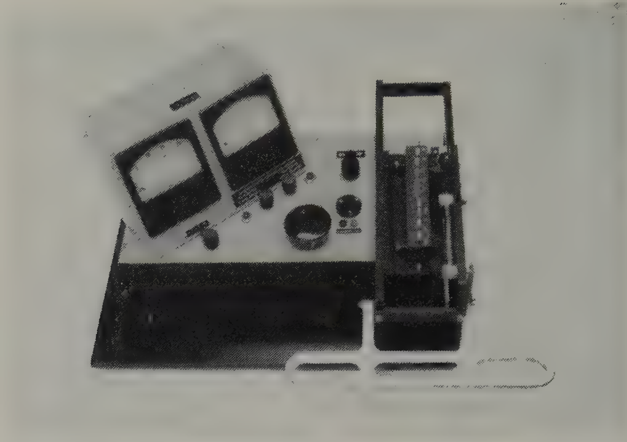


Fig. 13—V_p tester and shifting mechanism.

needles have a bend in them to grip the transistor leads. An improved model with lower inter-lead capacity is under development. It will be hollow and have wider lead spacing at the bottom.

The cartridge-shifting mechanism is shown in *Fig. 13*. A push on the lever advances the cartridge one notch, and the needles slide into the socket of the test box. The test chassis may be removed from the shifting mechanism for modification or repair. The $I_{c\ sat}$ and high-current β tests are shown in *Fig. 14*. No meters are used for the latter test, so a chart converting base current to β was installed on the chassis.

The testing rate has been estimated to be 600 transistors per hour. This figure is for four technicians loading and unloading the cartridges, and using seven test set-ups on a *go, no-go* basis.

Fig. 14—$I_{c\ sat}$ and β tests with associated equipment.

Acknowledgment

The authors wish to acknowledge the work of Gordon Essler in developing the cartridge and shifting mechanism.

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Constant Current Testing

WALTER H. BUCHSBAUM

Until very recently most of the testing done on electronic components and circuits depended on the indication or measurement of voltage as the major parameter. All the *vtvm*, multimeter and oscilloscope applications stress voltage rather than current. The reason for this concern with voltage can be easily understood when we remember that vacuum tubes, which used to be at the heart of any electronic equipment, are basically voltage sensitive devices. Only since the industry has turned to semiconductors and magnetic devices have we seen more emphasis on the measurement of current. This is due to the fact that the magnetic circuits and semiconductors are basically current sensitive devices.

A typical instance of the change from the consideration of voltage to a preoccupation with current is in the use of laboratory type power supplies. For vacuum tube applications it was essential that the B+ voltage remain constant with changes in load current, while in transistor circuits constant current is an important power supply characteristic. A quick comparison between a tube and a transistor manual will show that in the former voltage appears as the major parameter while for transistors the various currents are the vital statistics. Where we applied a bias voltage to the grid of a tube, we now inject a bias current into the base of a transistor. Wtih the increasing use of Zener and other diodes, as well as magnetic devices, current has emerged as a parameter of first importance. This has given rise to the development of an entirely new family of equipments—the constant current devices, which are the subjects of this article.

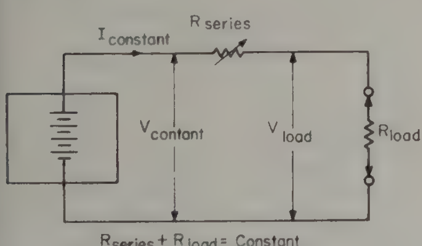

Fig. 1—Basic constant current circuit.

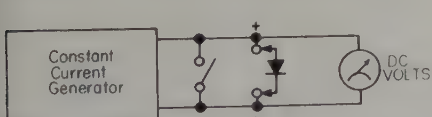

Fig. 2—Measurement of forward voltage drop of a rectifier.

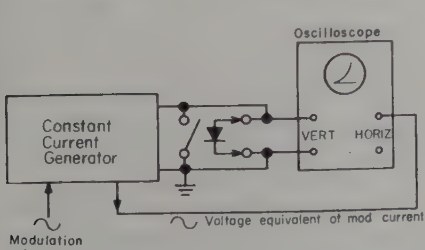

Fig. 3—Oscilloscope display of rectifier forward characteristics.

A constant current source is essentially a constant voltage power supply with a variable series impedance as illustrated by *Fig. 1.* The load current is kept constant regardless of changes in the load resistor. This is possible only if the series impedance is varied to compensate for variations in the load. If the power supply voltage is fixed, then the load voltage can range from zero up to the supply voltage, depending on the load resistance while the current remains constant. The concept of the variable series impedance, variable load and constant current is basic to an understanding of constant current test methods and many semiconductor characteristics.

Constant Current Applications

Before discussing some typical constant current equipments, a few examples of frequent applications are in order. When rectifiers are tested, whether in the laboratory or the production line, the important characteristics include the peak inverse voltage, the forward voltage drop for a given current, and the forward dynamic resistance. Occasionally, the forward characteristic curve of the rectifier is observed to check the voltage drop *vs.* forward current. All of these tests can be done efficiently when a constant current source is used with standard meters. *Fig. 2* shows the test set-up for measuring forward voltage drop at given current values. The switch in Figure 2 is kept closed until the rectifier is in the circuit so that sudden transient voltages cannot damage the rectifier. While the voltmeter indicates the forward voltage drop across the rectifier, the desired current is set at the constant current source. A typical constant current supply delivers anywhere from 1 microampere to 100 milliamperes with an absolute accuracy of 0.02%.

Peak inverse voltage can be measured by applying a current of reverse polarity to the rectifier and measuring the voltage across the rectifier. Because the current will be constant, regardless of the rectifier impedance, damage due to Zener breakdown will be avoided. The only requirement for this test method is that the constant current generator be capable of supplying the voltage levels corresponding to the peak inverse voltage of the particular rectifier.

To measure the forward dynamic impedance of a rectifier at a specific test current the same circuit as that shown in *Fig. 2* is used, but a small sinusoidal *a-c* current is superimposed on the rectifier by modulation of the constant current generator. An *a-c* voltmeter is used to measure the *a-c* voltage drop across the rectifier. The forward dynamic resistance is then found by Ohm's law as the ratio of the *rms* voltage to the *rms* current component.

To get an oscilloscope presentation of the forward characteristics of the rectifier, the test set-up shown in *Fig 3* would be used. The rectifier voltage is applied to the vertical input while a sine wave signal proportional to the *a-c* current is applied to the horizontal terminals. The plot then shows instantaneous rectifier voltage versus forward current. Zener diodes, transistors and even computer type diodes can be tested in a similar manner.

In addition to the above applications in semiconductor work, constant current sources are also very useful in magnetic component and circuit testing. The magnetic flux in a given coil is strictly a function of the current through the coil, regardless of voltage. As the coil heats up, the resistance increases which tends to reduce the current through it. When such a coil is connected to a constant current source, stable magnetic performance is assured, regardless of the thermal effect. In many types of transformers, toroid devices and other electro-magnetic components, the characteristics of the magnetic material must be investigated. Here again the current rather than the applied voltage is important and constant current sources are often the best means of testing magnetic components. A typical example of this is a method for testing ferrite memory cores in which Westinghouse uses a constant current source. Some of these current supplies can be pulse modulated with rise times as fast as 30 microseconds, and this permits testing under current pulse signals.

Still another application of the constant current source is in the field of optics. Filaments of precise optical lamps must be supplied with exactly known, constant current, regardless of the heating effect. In optical pyrometers, spectrographic instruments and colorimeters, the exact color of a reference light is determined by the current passing through its filament and for this reason constant current generators are used here.

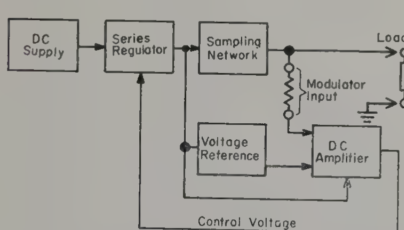

Fig. 4—Block diagram of constant current source.

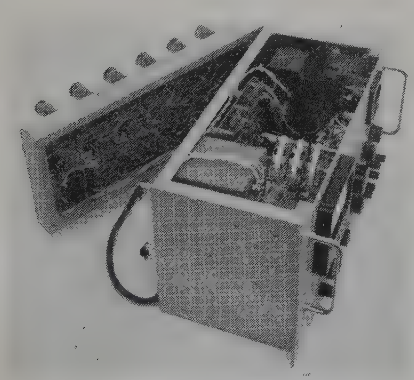

Fig. 5—Hinged subchassis facilitates maintenance. (North Hills Electric Co.)

Torque motors used in conjunction with synchro systems usually maintain constant torque by means of a constant current through the *d-c* windings and here again constant current supplies are used. There are numerous other, more unique applications of these devices, but as a matter of practical value, their greatest use occurs in the semi-conductor field.

Basic Circuit

The block diagram of *Fig. 4* shows the major components of a typical constant current supply. The *d-c* power supply is usually simply a voltage regulated *d-c* supply which feeds the series regulator and the load. The output current passes through the sampling network and the voltage drop at that point is applied to the *d-c* amplifier which compares it with the reference voltage. The amplified difference controls the series regulator impedance and thereby keeps the output current at the desired value. This value could be selected either by switching the sampling network or by varying the reference.

In some of the units the amplifier is a transistorized, straight *d-c* type with sufficient negative feedback to be stable, while in more precise current sources the differential amplifier uses a chopper to generate an *a-c* signal which is then amplified without the problems of *d-c* drifting. Considering the absolute accuracy of 0.02% required in output current, the amount of drift permissible in the voltage reference and amplifier dictates a very stable circuit.

Modulation of the output current is accomplished by impressing the modulating signal across a resistor which is in series with the error voltage as shown in *Fig. 4.* This small variation is amplified sufficiently to vary the impedance of the series regulator accordingly and produce a current variation exactly like the modulating signal. Generally, this resistor is small and any modulator must therefore have low output impedance. As mentioned before, by using complex waveshapes for the modulating signals, currents corresponding to the modulating waveshapes can be generated. Pulse currents are especially useful in determining transistor peak currents with varying duty cycles and without danger of destroying the component under test. For this application, the modulating signal must be applied with such a polarity that, in the absence of signal, zero current flows while the peak current pulse amplitude is determined by the adjustment of the sampling network in the constant current supply.

Actual Equipment

Like most commercial test equipment the various constant current sources now on the market are designed for standard rack mounting and use conventional, high quality construction. In almost all units considerable amounts of power must be dissipated and the chassis layout and component arrangement is therefore intended for the most efficient heat dissipation. Where power transistors are used they are usually mounted on specially designed heat sinks and frequently forced air cooling is added as well.

A typical construction technique which facilitates maintenance is illustrated in *Fig. 5.* Here the subchassis containing the regulator and amplifier sections is hinged at the rear of the main chassis and swings away for easy access to the tube sockets. The transformers and chokes are mounted on the front panel to avoid having the center of gravity at the rear of the unit. Precision resistors making up the switchable sampling network can be seen on a terminal board at the rear of the main chassis. This construction has the added advantage that the hottest components, the tubes, are located at the rear of the case, close to the ventilating holes, and do not contribute their heat to the other circuit parts.

Conclusion

Although constant current sources are not yet as widely used as their constant voltage equivalents ,it seems certain that the utility of this new device makes it an important tool in the semi-conductor field. Design engineers who have turned from vacuum tube circuits to transistors were required to change from a voltage point of view to the concept of current as a major parameter. This same change is also necessary in the test and measurement field. Constant current supplies, with suitable modulation, can serve as the cornerstone in setting up a whole system of tests and measurements for all types of semi-conductors. The other test equipment, such as scopes and meters, is usually already on hand and the reader will be familiar with it. Constant current generators, however, are relatively new and deserve some study as to their operation and various features.

Molecular Electronics Function Blocks*

WESTINGHOUSE IS now producing a variety of molecular electronic "function blocks," three of which are shown in *Fig. 1*. These are solid-state elements that achieve, entirely within themselves, electronic results such as have been gained only by assembling many, varied items of electronic hardware. Because of this, these elements are not intended as "components," as when reference is made to transistors and tubes, but rather as "subsystems." Examples of functions performed by function-blocks are such electronic operations as amplification, oscillation, and telemetering.

There are no internal connections or components, within these elements, and the only external connections needed are those for coupling inputs and outputs to make up the complete system.

Eight classes of function blocks have been developed to demonstrate the feasibility of molecular electronics at frequencies ranging from infrared to direct current. These function blocks are: (1) a 5-watt directly cascaded audio amplifier, (2) a two-stage video amplifier, (3) a frequency selective amplifier with notch filter in a feedback loop around the amplifier structure, (4) a variety of multivibrators—bistable, monostable and astable, (5) a variable potentiometer based on logarithmic addition of two inputs, (6) a variety of multiposition switches (including an "OR" switch, a multiple *n-p-n-p* Dynistor switch, and a multiple *n-p-n-p* Trinistor switch with firing electrode), (7) an analog-to-digital converter employing an *n-p-n-p* relaxation oscillator, and (8) a two-stage cooler, employing the Peltier effect, covering frequencies from 1 cycle or less to 3 megacycles, for cooling infrared detectors to proper operating temperatures.

As the basis for these molecular electronic subsystems, a very substantial knowledge of solid state phenomena has been developed over the past 30 years. It is simple now to create material having excessive positive or negative electrical charges and, by placing these materials in physical contact with related materials, to bring about such phenomena as rectification or amplification, as in diodes and transistors. Also, advantage can readily be taken of the

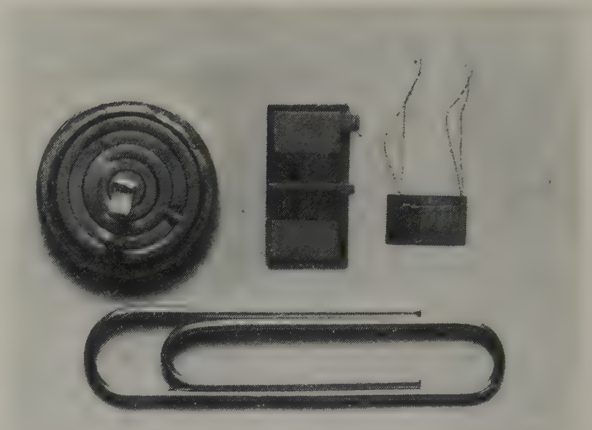

Fig. 1—Three of eight molecular electronic function blocks demonstrated as subsystems. Device bearing concentric arcs is an audio amplifier, at center is a free running multivibrator, and at right, a two-stage video amplifier.

ability of radiation to cause charge paths to occur in a semiconductor material along which current will flow when the material is irradiated.

Effects of this general type are used in molecular electronic blocks by creating—usually in single crystals—a number of distinct operative domains, which can be regarded as molecular "communities" having a common civic purpose, in that each domain will sustain a desired electronic occurrence. The domains border one another at boundaries called interfaces, which are like political frontiers in their ability to initiate phenomena different from those occurring inside the molecular domains.

As a simple example, in the element diagrammed in *Fig 2*, we see that it is composed of two domains which meet physically at one interface. One of these domains is composed of a resistive material selected and shaped to present a resistance R_1 to the passage of current; the other domain is also resistive, but is so planned that it has a resistance R_2. At the interface, the interaction between domains causes a capacitive effect. Thus, in one tiny element we have a subsystem equivalent to a time-delay circuit.

Another illustration of the uses of domains and interfaces is a function block designed as an *a-c* to *d-c* power supply for transistor circuits. It makes use of the Seebeck effect for the thermoelectric generation

***This represents a condensed version of a talk, "The Concepts and Capabilities of Molecular Electronics", by Dr. S. W. Herwald, Vice President-Research, Westinghouse Electric Corporation, at Washington, D.C. on Jan. 21, 1960.**

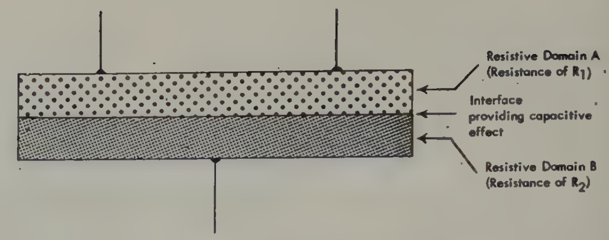

Fig. 2—Schematic drawing of function block of two resistive domains and one capacitive interface, whose total effect is that of an RC or time-delay circuit.

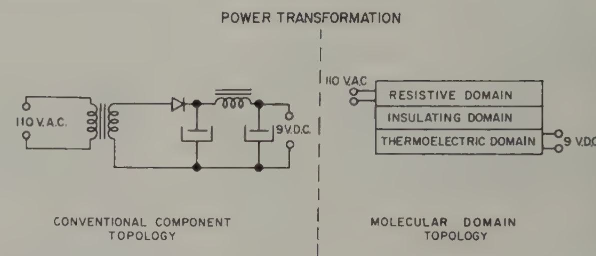

Fig. 3—Schematic drawing of a-c to d-c power supplies showixg (right) molecular element with resistive, electrical-insulating, and thermoelectric domains and (left) conventional method using transformer, diode, and filter circuit.

of electricity to convert 110-volt alternating current to 9-volt direct current power. Using molecular electronic methods, we have a function block comprised of the three separate domains. When *a-c* power is applied to the resistive domain, the heat that is generated passes through the domain at the center—this domain is an electrical but not a thermal insulator—and into the thermoelectric domain where the energy is converted into electrical energy by the Seebeck effect. By proper control over the materials used, we provide the 9-volt *d-c* output we desire. An interesting aspect of the power supply is that elimination of ripple as an undesirable variation in voltage is inherent since heat flows from the resistive domain to the thermoelectric domain at practically a constant rate.

As these two examples suggest, the concept of molecular electronics makes no use of the traditional circuit-and-component approach to electronics. Instead, the objective is to use our knowledge of the structure of matter to synthesize monolithic function blocks whose arrangement and composition permit each to serve as a substation to perform an electronic function in the control or transformation of energy.

To achieve function blocks with this capability, a number of effects and phenomena of the solid state are available. The only firm limitations on choice are that the effect must not react adversely on system reliability and must lend itself to consistent results when included in a funcion block. Methods typical of practice so far include: solid-state phenomena, such as Seebeck generation, Peltier cooling, and Hall-effect multiplication; the use of *p-n* semiconductor junctions arranged to produce a result which would otherwise require numerous individual components; and when necessary, fabrication of circuit elements within a function block. Although such phenomena will be most often used for the control of electrical signals, they will also be suitable when quantities like electromagnetic radiation, heat, and mechanical displacement are inputs or outputs.

The design of a subsystem begins with the designer's analysis of the requirements of the system, to establish the functions to be performed by the function block. After logic processes are determined and suitable physical effects settled upon, a topologist—a mathematician who works with shapes—determines the structure of the block by designing, on paper, the arrangement of domains and interfaces that is to control the flow of energy in the block. The block is then produced by the materials engineers who use germanium and silicon as the basic semiconductor materials.

In producing these blocks we do not assemble them from various tiny components. Rather, we start with a basic semiconductor wafer and produce the necessary domains and interfaces by techniques used in the production of conventional semiconductor devices, including diffusion, plating, electron beam machining, etching, cutting, radiation, alloying, and photographic processes. Although the function block so produced can now perform its function, additional processing steps are required to encapsulate the block, protect it against shock and vibration, and make it stable under the conditions of temperature and radiation it will encounter.

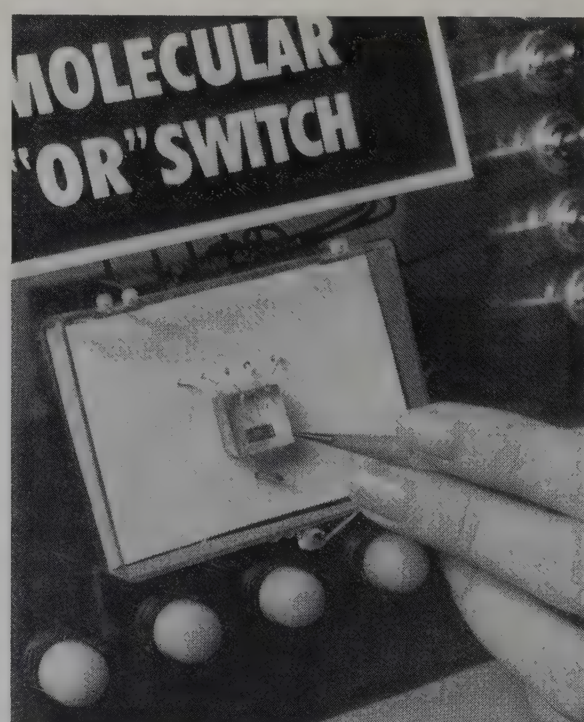

Fig. 4—A molecular electronic "or" switch.

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PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from July 16, 1957 to Aug. 27, 1957. In subsequent issues, patents issued from Aug. 27, 1957 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT Review will appear periodically, the treatment given to each item being more detailed.

July 16, 1957

2,799,784 Phase Comparison System—B. Harris, A. Macovski. A balanced phase comparator circuit which is free from changes in operating characteristics over a wide range of variation in ambient temperature.

2,799,814 Germanium Photodiode—B. Schwartz, P. M. Maloney. Assignee: Sylvania Electric Products, Inc. A method of forming a hermetically sealed and evacuated rectifying device by applying a conductive film to the exterior open-end portion of glass tube open at one end, inserting a rectifying junction subassembly into said tube, and inductively heating said film in an evacuated chamber in order to form a heat seal to a ceramic plug in the subassembly to the open end of said tube.

2,799,815 Dry Plate Rectifiers—L. J. Lockett. Assignee: Westinghouse Brake and Signal Co., Ltd. A rectifier assembly including a metal case enclosing two stacks of rectifier elements, a contact member, a conducting resilient member associated with each stack, and making contact at the end thereof remote from a connecting strip between said stacks, said contact member making connection with each resilient member.

July 23, 1957

2,800,559 Electrical Semiconductors Comprising Organo-Metallic Compounds and Process of Producing Same—A. R. Ubbelohde. Assignee: National Research Development Corp.

2,800,617 Semiconductor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A semiconductor switching or modulating device and system, the electrode construction and arrangement of which provides efficient operation and good high-frequency performance.

July 30, 1957

2,801,297 Feedback Stabilized Transistor Amplifier—A. G. Becking, P. Boxman. Assignee: North American Phillips Co., Inc. A circuit comprising an odd number of cascade arranged amplifier stages, each of said stages comprising a transistor, a supply source, a *d.c.* coupling impedance connected between said source and the collector electrode, means for stabilizing the operating point of said transistor and signal input and output means.

2,801,298 Series Connected Transistor Amplifier—R. N. Metal. Assignee: North American Phillips Co., Inc. An amplifier comprising an electron tube and two transistors; means for connecting the plate of the tube to the base electrode of one transistor, the emitter to the base of a second transistor, and the collector of the first to a point of reference potential; a common source of energy; and an output load impedance between the second collector and the reference point.

2,801,329 Assembly Fixture—J. B. Gray II, W. R. Yeich. Assignee: Western Electric Co., Inc. An assembly fixture for facilitating the accurate positioning and attaching of the base members of point-contact devices to their support members.

2,801,338 High Sensitivity Voltage Comparator Circuit—J. W. Keller Jr. Assignee: U.S.A. (Department of the Army). A circuit adapted to switch from a quiescent to an oscillatory state upon receiving a triggering voltage in excess of a predetermined value.

2,801,340 Semiconductor Wave Generator—E. Keonjian, J. J. Suran. Assignee: General Electric Corporation. A relaxation oscillator circuit using a semiconductor device which has only a single rectifying junction.

2,801,345 Regenerative Pulse Translating Circuit—J. P. Eckert Jr., T. H. Bonn. Assignee: Sperry Rand Corporation. A pulse translating circuit utilizing a transistor amplifier in which all of the transistor circuit output is employed for regeneration when the input pulse is first received, and later all of the output energy of the transistor is fed to the outputs of the system.

2,801,346 Electrical Dipole Having a Comparatively Low Direct Current and a Comparatively High Alternating Current Impedance—J. J. Rongen, H. H. VanAbbe. Assignee: North American Phillips Co., Inc. A two terminal network comprising the series combination of the collector-emitter path of a transistor and of a resistor which is connected to the emitter thereof, said network exhibiting an impedance considerably larger than its direct current resistance.

2,801,347 Multielectrode Semiconductor Devices—S. W. Dodge, Jr. Assignee: Radio Corporation of America. A device comprising a semiconductive body, a plurality of *p-n* junction input electrodes in contact with a surface of body, a *p-n* junction output electrode in contact with an opposite surface of said body, and an ohmic base mounted on said body.

2,801,348 Semiconductor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A device having means for providing an electric field to control current flow within said body and a rectifying electrode for controlling said field and said current flow.

2,801,374 Relay Device—C. G. Svala. Assignee: Telefonaktiebolaget L. M. Ericsson (Sweden). A relay device comprising a transistor amplifier and an electromagnetic relay arranged in a circuit in which positive feedback is obtained from the output to the input of the amplifier, and in which the input impedance of the device is high for control signals at the same time as low impedance is obtained for the feedback current.

2,801,375 Silicon Semiconductor Devices and Processes for Making Them—E. F. Losco. Assignee: Westinghouse Electric Corporation. A semiconductor rectifying device including a silicon member bonded to a heat absorbing and dissipating contact member by means of a silver base solder composed of over 50% silver, an amount of antimony and at least one other element from the group consisting of tin, silicon, lead and germanium.

2,801,376 Alloys and Rectifiers Made Thereof—K. Lark-Horovitz, R. M. Whaley. Assignee: Purdue Research Foundation. A semiconductor point-contact device composed of 99% pure germanium and at least one of the elements from the group consisting of chromium and uranium, said device having a peak back voltage in excess of 10 volts and approaching 200 volts.

2,801,383 Voltage Regulator—J. S. Comins, P. J. Gallagher. Assignee: Sorenson & Company, Inc. A voltage regulator with a sensing system which can be adjusted to approximate the *r-m-s*, peak, or average voltage across a load circuit.

August 6, 1957

2,802,065 Cascade Connected Common Base Transistor Amplifier Using Complimentary Transistors—G. C. Szeklai. Assignee: Radio Corporation of America. A direct-coupled semiconductor amplifier circuit requiring only a single source of bias voltage for the output electrode of the driving transistor and the input electrode of the driven transistor.

2,802,067 Symmetrical Direct Current Stabilization in Semiconductor Amplifiers—J. Zawels. Assignee: Radio Corporation of America. An invention utilizing semiconductor devices of opposite con-

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

ductivity type in a direct-current symmetrical arrangement in which differences in said devices involving a change of collector current saturation will act to affect the operating stability of said devices.

2,802,071 Stabilizing Means for Semiconductor Circuits—H. C. Lin. Assignee: Radio Corporation of America. In a signal conveying circuit a pair of temperature sensitive germanium diodes are used to establish and control the bias conditions between the base and emitter electrodes of one or more transistors.

2,802,117 Semiconductor Network—V. P. Mathis, J. J. Suran. Assignee: General Electric Company. This semiconductor network was designed to improve the uniformity of circuit response to input signals of various characteristics, to improve the definition of states in multiple stable semiconductor networks, and to reduce variations in reset pulse requirements of a bistable semiconductor network.

2,802.118 Transistor Amplifier Circuits—Q. W. Simkins. Assignee: Bell Telephone Laboratories. A transistor amplifier in which the entire collector current during build-up flows in a distinct feedback secondary windings, and in a feedback path, so as to assure rapid build-up of collector current.

2,802,149 Contact Protection Circuits—L. H. Germer, J. L. Smith. Assignee: Bell Telephone Laboratories. In a contact protection circuit, a pair of contacts to be protected, a *d-c* load circuit, a connection from said circuit to one of said contacts, a circuit comprising the parallel arrangement of a *p-n* junction rectifier and an inductance connected between the load and the other contact, and a condenser across the load terminals.

2,802,158 Metal Rectifier Assemblies—A. H. Walker, L. J. Lockett. Assignee: Westinghouse Brake and Signal Co., Ltd. A rectifier having the stacks thereof housed in holes formed in a block of insulating material, said block then being covered by an insulating sheet having metallic connections on the inside surface thereof, said connections making contact with rectifier elements.

2,802,159 Junction Type Semiconductor Devices—H. Stump. Assignee: Hughes Aircraft Company. A fusion type semiconductor device in which the resistance of the base region is approximately five ohms, said device being formed by depositing a metallic layer on the base region immediately adjacent to the rectifying barrier.

2,802,160 Intermediate Zone Locating Servo-System—W. E. Engeler. Assignee: General Electric Company. Apparatus for automatically locating on a semiconducting surface an area on one conductivity type bordering on each of two sides by an area of opposite conductivity type.

August 13, 1957

2,802,759 Method for Producing Evaporation Fused Junction Semiconductor Devices—L. Moles. Assignee: Hughes Aircraft Company. A method of producing an integral regrown crystal region of one conductivity type upon a surface of a semi-conductor crystal body having a predetermined conductivity type by means of a process that involves the evaporation and deposition of impurity containing layer upon said surface.

2,802,760 Oxidation of Semiconductive Surfaces for Controlled Diffusion—L. Derick, O. J. Frosch. Assignee: Bell Telephone Laboratories. A process for treating semiconductive silicon wafers by depositing an oxide layer on the surface thereof, removing portions of said oxide film, and reheating said wafer in an impurity containing atmosphere in such a manner as to create surface regions of opposite conductivity type.

2,802,938 Diode Detector—Transistor Amplifier Circuit for Signal Receivers—G. B. Herzog; Assignee: Radio Corporation of America. Means in a radio signal receiver for directly coupling a diode rectifier detector to a transistor amplifier and by so doing enabling a separate load circuit for the rectifier to be eliminated.

2,802,954 A-C Coupled Gate Circuits—R. E. Graham, E. R. Ketzmer. Assignee: Bell Telephone Laboratories. In a gate circuit, the duration of the "on" period of the gate is independent of the duration of the control voltage signal but is determined by the time constant of the charging capacitor and the impedance associated with its charging path.

2,802,973 Selenium Rectifiers—E. L. French. Assignee: Westinghouse Brake and Signal Co., Ltd. A selenium rectifier cell comprising a base plate, a selenium layer thereon, a non-genetic layer of saccharide on said selenium layer, and a counter-electrode layer on said non-genetic layer.

2,802,974 Selenium Rectifiers—E. L. French. Assignee: Westinghouse Brake and Signal Co., Ltd. In a selenium cell, a base plate, a selenium layer thereon, a non-genetic layer of prolamine on the selenium, and a counter electrode on the prolamine layer.

August 20, 1957

2,803,569 Formation of Junctions in Semiconductors—H. Jacobs, J. R. Liebowitz, A. P. Ramsa. Assignee: U.S.A. (Department of the Army). A method of producing a semiconducting silicon body having a predetermined conductivity type by subjecting a block of silicon to electron bombardment to render chemically clean the surface of said block, and then evaporating a significant impurity onto the bombarded surface.

2,803,758 Transistor Amplifier Clipping Circuit—R. M. Whitenack. Assignee: International Business Machines Corporation. A two-stage amplifier for producing a large square wave output signal in response to a small sinusoidal input signal.

2,803,799 Electron Switching Device—E. S. Rittner, I. E. Grace, S. Fine, G. A. Beutel. Assignee: North American Phillips Co., Inc. A switching system comprising a cathode, a target electrode surrounding said cathode and composed of four sections, each including a pair of spaced terminals and a photoconductive semiconductor therebetween, and a pair of amplifying systems connected to four deflecting blades, one system to a pair of blades.

2,803,791 Blocking Layer Rectifier Cells—J. J. Van Amstel, A. Von Wierengen. Assignee: North American Phillips Co., Inc. A blocking rectifier assembly comprising an electrically conductive supporting plate and a plurality of spaced rectifier cells each comprising a semiconductive body constituting an electrode of each of said cells, the total area occupied by all of the semiconductive bodies being less than one-half the surface area of the supporting plate.

August 27, 1957

2,804,405 Manufacture of Silicon Devices—R. Derick, C. J. Frosch. Assignee: Bell Telephone Laboratories. In the manufacture of a silicon semiconductive device, the process of forming on the surface of a silicon body and selectively removing therefrom portions of a phosphorus film, treating the surface in order to deposit a boron film on said selected portions, and heating the body to form two diffused layers containing one of these elements.

2,804,580 Unidirectionally Conducting Elements—J. M. Hanlet. Assignee: J. Visseaux S.A. (France). A unidirectional conducting element having a layer of germanium and superimposed thereon a discontinuous dielectric layer which on a molecular scale presents a network of tightly joined meshes, and a continuous conducting film which contacts the germanium layer through the meshes in the dielectric layer.

2,804,581 Semiconductor Device and Method of Manufacture; Thereof—F. Lichtgarn. Assignee: Sarkes Tarzian, Inc. A semiconductor device wherein the electrical characteristics of the device may be readily enrolled so that a greater percentage of the devices are within commercial tolerances.

2,804,583 Direct Current Motor Speed Control System—L. L. Genuit. Assignee: General Electric Company. A *d-c* motor speed control system incorporating a single inductive device and providing adequate compensation for armature drop.

2,804,584 Direct Current Motor Speed Control System—M. A. Sims. Assignee: General Electric Company. A *d-c* motor speed control system having good regulation of motor speed for changes in motor load, said regulation being accomplished by utilizing one magnetic core.

2,804,595 Pulse Modulation Circuit—R. O. Soffel. Assignee: Bell Telephone Laboratories. An arrangement for preventing spurious transmission of carrier in a pulse modulation system during the absence of signal pulse, and to preserve the same terminating impedance for the carrier source in a pulse modulation system during both the presence and absence of a signal pulse.

2,804,596 Balanced Amplitude Modulation with Reinserted Carrier—V. J. Hawks. Assignee: Bell Telephone Laboratories. A method for balancing out voice signals from a double sideband A.M. system and still transmit the carrier with upper and lower sidebands.

(To be continued)

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN OCT. 1, 1959 and NOV. 30, 1959 ONLY. This is a partial listing and will be continued in the next issue

MANUFACTURERS

AEG—	Allgemeine Elekticitats-Gesellschaft
AEI—	Associated Electrical Industries, Ltd.
AMP—	Amperex Electronic Corp.
AUD—	Audio Devices, Inc.
BEN—	Bendix Aviation Corp.
BER—	Berkshire Labs
BOG—	Bogue Electric Mfg. Co.
BOM—	Bomac Labs
BRA—	Bradley Labs
CBS—	CBS Electronics
CDC—	Continental Device Corp.
COL—	Columbus Electronics Corp.
CTP—	Clevite Transistor Products, Inc.
CSF—	Compagnie Generale de T.S.F.
DAL—	Dallons Semiconductor
DEL—	Delco Radio
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GIC—	General Instrument Corp.
GTC—	General Transistor Corp.
HAFO—	Institutet for Halvedarforskning
HSD—	Hoffman Semiconductor Division
HUG—	Hughes Products Division
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
LCTF—	Laboratoire Central de Telecommunications
MAL—	P. R. Mallory & Co., Inc.
MIC—	Microwave Associates, Inc.
MOT—	Motorola, Inc.
MUL—	Mullard, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHM—	Ohmite Manufacturing Co.
PHI—	Philco Corp. Lansdale Tube Company
PSI—	Pacific Semiconductors, Inc.
QSC—	Qutronic Semiconductor Corp.
RAY—	Raytheon Company
RCA—	Radio Corporation of America, Semiconductor Div.
RHE—	Rheem Semiconductor Corp.
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
TI—	Texas Instruments, Inc.
TKD—	Tekade, Nurnberg, Germany
TOK—	Tokyo Tsushin Kogyo, Ltd.
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
UCI—	United Components
USD—	United States Dynamics Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered diodes and rectifiers.

CONTINENTAL DEVICE: 1N625 thru 1N629, 1N643, 1N643A, 1N658 thru 1N663, 1N662A, 1N663A,1N703A thru 1N721A, 1N721, 1N746 thru 1N759, 1N746A thru 1N759A, 1N778,1N779,1N789 thru 1N804, 1N806 thru 1N809, 1N818, 1N821 thru 1N826, 1N837, 1N837A, 1N838, 1N840, 1N841, 1N846 thru 1N849, 1N857, 1N858, 1N859, 1N860, 1N868, 1N869, 1N870, 1N871, 1N879, 1N880, 1N881, 1N882, 1N891, 1N892, 1N893

DALLONS: 1N248A, N248A,1N249A,1N250A,1N1183,1N1184, 1N1186 thru 1N1190,1N1434 thru 1N1438,1N2154 thru 1N2158,1N2160

GENERAL TRANSISTOR: 1N66A,1N67,1N67A, 1N68, 1N68A, 1N88, 1N89, 1N90, 1N95 thru 1N100, 1N96A thru 1N100A, 1N102, 1N107, 1N108, 1N116, 1N116A, 1N117, 1N117A, 1N118, 1N118A, 1N126, 1N127, 1N128, 1N191, 1N192, 1N198, 1N270, 1N276, 1N277, 1N279, 1N281, 1N283, 1N287 thru 1N292, 1N294A, 1N297, 1N298A, 1N304,1N308, 1N309, 1N310, 1N313, 1N480, 1N490, 1N497 thru 1N502, 1N631 thru 1N634, 1N636

HUGHES: 1N126A, 1N127A, 1N191, 1N192, 1N547

INTERNATIONAL RECTIFIER: 1N1199 thru 1N1205, 1N1341 thru 1N1347

SPERRY: 1N456, 1N461 thru 1N464, 1N488, 1N488A, 1N643, 1N645 thru 1N649, 1N658, 1N659, 1N660, 1N662, 1N663, 1N789 thru 1N796, 1N837, 1N837A, 1N840, 1N844

SYLVANIA: 1N456 thru 1N459, 1N456A thru 1N459A, 1N461 thru 1N464, 1N461A thru 1N464A, 1N482 thru 1N488, 1N482A thru 1N486A, 1N482B thru 1N486B, 1N625 thru 1N628, 1N770,1N1610, 1N1692 thru 1N1695, 1N2069, 1N2070, 1N2071, 1N2127

UNITED COMPONENTS: 1N456 thru 1N459,1N456A,thru 1N459A, 1N461 thru 1N464, 1N461A thru 1N464A, 1N482 thru 1N488, 1N482A thru 1N488A, 1N482B thru 1N486B, 1N625 thru 1N629, 1N658 thru 1N663

VICKERS: 1N255, 1N256, 1N332 thru 1N338, 1N341, 1N342, 1N343, 1N553, 1N554, 1N555, 1N1118, 1N1119, 1N1120

NEW DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
1N771	1	Ge	100	80	100	1.0	.065	25A		25	50	25A	GTC
1N771A	1	Ge	100	80	.200	1.0	.075	25A		25	50	25A	GTC
1N771B	1	Ge	100	80	400	1.0	.10	25A		25	50	25A	GTC
1N772	1	Ge	80	70	100	1.0	.065	25A		50	50	25A	GTC
1N772A	1	Ge	80	70	200	1.0	.075	25A		50	50	25A	GTC
1N773	1	Ge	75	65	100	1.0	.065	25A		100	50	25A	GTC
1N773A	1	Ge	75	65	200	1.0	.075	25A		100	50	25A	GTC
1N774	1	Ge	70	60	100	1.0	.065	25A		150	50	25A	GTC
1N774A	1	Ge	70	60	200	1.0	.075	25A		150	50	25A	GTC
1N775	1	Ge	70	60	100	1.0	.065	25A		250	50	25A	GTC

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Ø Insulated Base

5. Controlled Rectifier
6. Dual Rectifier

△ Direct Tube Replacement

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

Ø Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ — Inlet Temperature of Coolant

Type No.

† —Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

Under E_f

Ø - at 125^0C

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C: I_f (mA)	@ E_f (volts)	MAX. D.C. OUTPUT CURRENT[4] (amps)	@ T (°C)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current: I_b (uA)	@ E_b (volts)	@ T (°C)	MFR. (See code at start of charts)
1N776	1	Ge	30	20	50	1.0	.05	25A		200	10	25A	GTC
1N1183A	2	Si	50		100A	1.1	40	150	1.1	5000	50	150C	DEL
1N1184A	2	Si	100		100A	1.1	40	150	1.1	5000	100	150C	DEL
1N1185A	2	Si	150		100A	1.1	40	150	1.1	5000	150	150C	DEL
1N1186A	2	Si	200		100A	1.1	40	150	1.1	5000	200	150C	DEL
1N1191A	2	Si	50		60A	1.2	22	150	1.2	5000	50	150C	DEL
1N1192A	2	Si	100		60A	1.2	22	150	1.2	5000	100	150C	DEL
1N1193A	2	Si	150		60A	1.2	22	150	1.2	5000	150	150C	DEL
1N1194A	2	Si	200		60A	1.2	22	150	1.2	5000	200	150C	DEL
D2030	2,3	Si	300	300			20	25A	.60	5000	300	150	DAL
D2040	2,3	Si	400	400			20	25A	.60	5000	400	150	DAL
D2050	2,3	Si	500	500			20	25A	.60	5000	500	150	DAL
D2060	2,3	Si	600	600			20	25A	.60	5000	600	150	DAL
D3030	2,3	Si	300	300			30	25A	.60	5000	300	150	DAL
D3050	2,3	Si	500	500			30	25A	.60	5000	500	150	DAL
R2105	2	Si	50	35	same as S2105 but reverse polarity								SYN
R2110	2	Si	100	70	same as S2110 but reverse polarity								SYN
R2115	2	Si	150	105	same as S2115 but reverse polarity								SYN
R2120	2	Si	200	140	same as S2120 but reverse polarity								SYN
R2125	2	Si	250	175	same as S2125 but reverse polarity								SYN
R2130	2	Si	300	210	same as S2130 but reverse polarity								SYN
R2135	2	Si	350	245	same as S2135 but reverse polarity								SYN
R2140	2	Si	400	280	same as S2140 but reverse polarity								SYN
R3305	2	Si	50	35	same as S3305 but reverse polarity								SYN
R3310	2	Si	100	70	same as S3310 but reverse polarity								SYN
R3315	2	Si	150	105	same as S3315 but reverse polarity								SYN
R3320	2	Si	200	140	same as S3320 but reverse polarity								SYN
R3325	2	Si	250	175	same as S3325 but reverse polarity								SYN
R3330	2	Si	300	210	same as S3330 but reverse polarity								SYN
R3335	2	Si	350	245	same as S3335 but reverse polarity								SYN
R3340	2	Si	400	280	same as S3340 but reverse polarity								SYN
RD1356	1,3	Si	30		100	1.0	.070	150		5.0	25	150	RHE
RD1357	1,3	Si	70		100	1.0	.070	150		5.0	60	150	RHE
RD1358	1,3	Si	150		100	1.0	.070	150		5.0	125	150	RHE
RD1359	1,3	Si	200		100	1.0	.070	150		5.0	175	150	RHE
S262	1	Si	30	15	3.0	1.0	.03	55		150	15	55	AMP
S2105	2	Si	50	35	25A	1.5	13	25A	1.0	5000	50	150C	SYN
S2110	2	Si	100	70	25A	1.5	13	25A	1.0	5000	100	150C	SYN
S2115	2	Si	150	105	25A	1.5	13	25A	1.0	5000	150	150C	SYN
S2120	2	Si	200	140	25A	1.5	13	25A	1.0	5000	200	150C	SYN
S2125	2	Si	250	175	25A	1.5	13	25A	1.0	5000	250	150C	SYN
S2130	2	Si	300	210	25A	1.5	13	25A	1.0	5000	300	150C	SYN
S2135	2	Si	350	245	25A	1.5	13	25A	1.0	5000	350	150C	SYN
S2140	2	Si	400	280	25A	1.5	13	25A	1.0	5000	400	150C	SYN
S3305	2	Si	50	35	50A	1.3	25	25A	1.0	5000	50	150C	SYN
S3310	2	Si	100	70	50A	1.3	25	25A	1.0	5000	100	150C	SYN
S3315	2	Si	150	105	50A	1.3	25	25A	1.0	5000	150	150C	SYN
S3320	2	Si	200	140	50A	1.3	25	25A	1.0	5000	200	150C	SYN
S3325	2	Si	250	175	50A	1.3	25	25A	1.0	5000	250	150C	SYN
S3330	2	Si	300	210	50A	1.3	25	25A	1.0	5000	300	150C	SYN
S3335	2	Si	350	245	50A	1.3	25	25A	1.0	5000	350	150C	SYN
S3340	2	Si	400	280	50A	1.3	25	25A	1.0	5000	400	150C	SYN
S5130	2	Si	10400	7400			.30	100	22	2000	10400	25	SAR
S5162	2	Si	2800	1950			.50	100	12	2000	2800	25	SAR
S5343	2	Si	7000	5000			.30	100	16	2000	7000	25	SAR
ZR15	2	Si	500	500	750	1.0	.75	25A	1.0	50	500	25A	FERB
ZR15T	2	Si	500	500	750	1.0	.75	25A	1.0	50	500	25A	FERB
ZR15TR	2	Si	500	500	same as ZR15T but reverse polarity								FERB
ZR33C	2	Si	300	300	30A	1.2	30	25A	1.2	500	300	25A	FERB
ZR33R	2	Si	300	300	same as ZR33C but reverse polarity								FERB
ZR34C	2	Si	400	400	30A	1.2	30	25A	1.2	500	400	25A	FERB
ZR34CR	2	Si	400	400	same as ZR34C but reverse polarity								FERB
ZS33A	1	Si	300	300	500	1.1	.50	25A	1.1	.20	300	25A	FERB
ZS33B	1	Si	300	300	500	1.1	.50	25A	1.1	5.0	300	25A	FERB
ZS34A	1	Si	400	400	500	1.1	.50	25A	1.1	.20	400	25A	FERB
ZS34B	1	Si	400	400	500	1.1	.50	25A	1.1	5.0	400	25A	FERB

(Continued on following page)

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFI-CATION	DESCRIPTION	MFR.
1N21F	2	Receiver N.F.- 5.5-6.0db. from 300 to 4000Mc	MIC
1N78D	1,2	Silicon; 16000Mc. mixer; Conv. loss 5.7db max.;	SYL
		Receiver N.F. - 7.5db. max.	PHI
1N79	1,2	Meter Rectifier up to 3000 Mc.	SYL
1N630A	1,2	1000-12,000Mc.;Fig. of Merit-30min.;Sens.-40dbm	SYL
1N831A	1	Improved Micro-Min S-band mixer	SYL
1N1611	1,2	9000Mc.; Fig.of Merit-130min.	SYL
1N1611A	1	Improved X-band video detector	SYL
1N2510	1	Coaxial X-band mixer	SYL
1N2782	2	UHF detector	SYL
1N2792	1,2	Germanium; 70000Mc mixer; Conv. loss 10db max.; NR 2.5 max.; NF 13db max.;Rcvr. NF 13.8db max.	PHI
2A	5	Si;Area-1.125in. dia;PO-34mw at 10000 ft. cndls	HSD
3A30A	9	Anode V.-30V.max; Gate V. to fire- .40-.80V	SSP
3A31	9	Anode V.-30V.max; Gate V. to fire- .44-.60V	SSP
3A60A	9	Anode V.-60V.max; Gate V. to fire- .40-.80V	SSP
3A61	9	Anode V.-60V.max; Gate V. to fire- .44-.60V	SSP
3A100A	9	Anode V.-100V.max; Gate V. to fire-.40-.80V	SSP
3A101	9	Anode V.-100V.max; Gate V. to fire-.44-.60V	SSP
3A200A	9	Anode V.-200V.max; Gate V. to fire-.40-.80V	SSP
3A201	9	Anode V.-200V.max; Gate V. to fire-.44-.60V	SSP
51C	5	Si;Area-.5x1in.;PO- 3.0mw at 10000 ft. cndls.	HSD
52C	5	Si;Area-.5x2in.;PO- 6.0mw at 10000 ft. cndls.	HSD
55C	5	Si;Area-.5x.5in.;PO- 1.5mw at 10000 ft. cndls.	HSD
58C	5	Si;Area-.5x.25in.;PO- .72mw at 10000 ft, cndls.	HSD
110C	5	Si;Area-.4x.4in.;PO- 6.8mw at 10000 ft. cndls.	HSD
120C	5	Si;Area-.4x.8in.;PO- 13.6mw at 10000 ft. cndls.	HSD
200A	5	Si;Area- .281in. dia;PO- 8.4mw at 10000 ft. cndls	HSD
220C	5	Si;Area- .8x.8in.;PO- 26mw at 10000 ft. cndls.	HSD
D4005	1,2	3060Mc.; Rcvr. N.F.- 6.5db	SYL
D4066	1,2	UHF Mixer	SYL
D4070	1,2	3295Mc.; Fig. of Merit- 85min.	SYL
D4080	1,2	34860Mc.; Lc-6.5db. max.; NR-2 max.	SYL
D4081	1,2	16000Mc.; Lc-5.7db. max.; NR-1.3max	SYL
D4081A	1,2	16000Mc.; Lc-5.7db. max.; NR-1.3max	SYL
D4089	1,2	23984Mc.; Lc-6.5db. max.; NR-1.5max.	SYL
D4090	1,2	9375Mc.; Rcvr. N.F.-7db. max.	SYL
DS1D	9	Switching V.-100V.; off Current-.05ua max. Sustaining I -200ua max.	FERB
DS1E	9	Switching V.-100V.; off Current-.05ua max. Sustaining I -2.0ma max.	FERB
DS1F	9	Switching V.-100V.; off Current-.05ua max. Sustaining I -10ma max.	FERB
DS1G	9	Switching V.-100V.; off Current-.05ua max. Sustaining I -25ma max.	FERB
N2009	5	9 per cent eff.; .53V. min. open circuit voltage; 36ma min. short circuit current.	TII
TD100	10	V.range neg. slope-65-280mv; Peak I- 1.5-7.6ma.	RCA
TD101	10	V.range neg. slope-65-280mv; Peak I- 1.5-3.1ma.	RCA
TD102	10	V.range neg. slope-65-280mv; Peak I- 2.9-5.2ma.	RCA
TD103	10	V.range neg. slope-65-280mv; Peak I- 4.2-7.6ma.	RCA
TD104	10	V.range neg. slope-65-280mv; Peak I- 1.5-2.1ma.	RCA
TD105	10	V.range neg. slope-65-280mv; Peak I- 1.9-2.5ma.	RCA
TD106	10	V.range neg. slope-65-280mv; Peak I- 2.3-3.1ma	RCA
TD107	10	V.range neg. slope-65-280mv; Peak I- 2.9-3.7ma	RCA
TD108	10	V.range neg. slope-65-280mv; Peak I- 3.5-4.4ma	RCA
TD109	10	V.range neg. slope-65-280mv; Peak I- 4.2-5.2ma	RCA
TD110	10	V.range neg. slope-65-280mv; Peak I- 5.0-6.3ma	RCA
TD111	10	V.range neg. slope-65-280mv; Peak I- 6.1-7.6ma	RCA

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
3. Varactor diodes
4. Photodiodes
5. Solar Cells
6. Harmonic Gererator diodes
7. 4-Layer bistable diodes
8. Controlled rectifier
9. PNPN Switch
10. Tunnel Diode

Note: Other diode types will be listed in the March issue of SCP.

New Products

High-Current Switching Diodes

Sperry Semiconductor Division 1N920-1N923 series high-conduction, fast-recovery diodes have met the most severe requirements of high-current pulse circuits for computer switching, pulse clamping, gating, blocking and diode logic circuits. These 0.3 microsecond, ½-ampere devices, designed for high-temperature operation (to 175°C), feature high forward conductance (500mA at 1 volt maximum drop) and low leakage (50μA maximum at 150°C).

Circle 69 on Reader Service Card

Computer Diodes

TI 1N914 and TI 1N916, fast high voltage silicon mesa diodes were made commercially available by Texas Instruments Incorporated. The new diffused devices switch from 10 ma forward current to six volts reverse in four millimicroseconds maximum. Both devices will dissipate 250 mw of power at 25°C and highlight a guaranteed minimum forward voltage of 1 volt at 10 milliamps. Through the use of silicon mesa construction, both diodes have an operating range of —65 to 150°C and a maximum storage temperature of 200°C.

Circle 63 on Reader Service Card

Solid State Power Supplies

Electronic Research Associates announces two new additions to their line of Magitran transistor-magnetic high current regulated power supplies. The new units provide regulated outputs in the range 0-36 VDC with current ratings up to 30 and 50 amperes respectively. Other specifications include input 105-125 VAC, 60 cps, line regulation within plus or minus 0.05%, load regulation less than 0.1% and ripple less than 2 millivolts.

Circle 70 on Reader Service Card

Tubular Sintered-Anode Capacitors

For applications where a superior quality, reliable design for military applications is desired, Sprague Type 109D tubular sintered-anode Tantalex capacitors fill the basic military requirements. May be operated up to 85 C at rated d-c working voltage and may be operated up to 105 C with a voltage derating of only 15%. This design will meet the 2000 cycle military missile vibration requirements.

Circle 71 on Reader Service Card

Switching Transistor

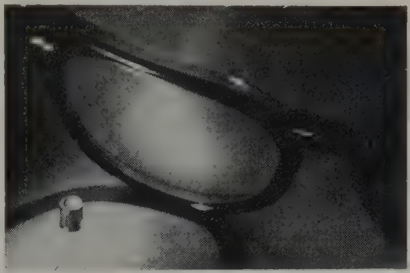
Military-type 2N1011 germanium pnp power transistor is being produced by Bendix Aviation Corporation. Designed to meet specification MIL-T-19500/67 (SigC), it has a 5 ampere maximum current rating, a current gain range of 30-75 at Ic—3 Adc, and a maximum collector-base voltage rating of 80 volts. It will readily dissipate 35 watts at 25°C mounting base temperature. Stringent environmental testing required by the specification assures the high reliability demanded in military applications.

Circle 68 on Reader Service Card

Electronic "Building Block"

General Electric has made sample quantities of its second tunnel diode, a 1000 megacycle device, available to electronic industry designers. Features of the ZJ-56A include a minimum peak to valley current ratio of 5 to 1, a typical peak point current rating of 1-milliampere, which is held to plus or minus ten percent, and a typical negative conductance of 0.065-mho. Rated for an operating junction temperature of minus 55°C to plus 100°C, has typical peak point voltage of 55-millivolts and typical valley point voltage of 350-millivolts.

Circle 61 on Reader Service Card



Minute Rectifiers

Subminiature silicon rectifiers with inverse-voltage ratings covering the entire spectrum from 50 to 1000 volts are available from the semiconductor division of Hughes Aircraft Company. The new series includes over 44 diode types (assigned Jedec No's 1N846 to 1N889 inclusive) divided into four basic groups, with maximum surge current ratings of 0 5, 1.0, 1.5, and 2.0 amperes, and maximum average rectified current ratings of 50, 100, 150, and 200 milliamperes. Temperature limitations for storage are —65°C and 200°C.

Circle 62 on Reader Service Card

Sub-miniature Tape Recorder

A two-channel miniature tape recorder now being manufactured by Precision Instrument Company measures only 5" by 4" by 2" complete, including all electronics. Total weight is 2 pounds. Power requirements are only 2½ watts (dc source). The unit includes electronics for record and reproduce and a timing reference source. The latter is 1 kc, ±0.01 percent. The tiny recorder will operate at any tape speed up to 48 ips, bi-directional, with end-of-tape sensing. Frequency response is up to 160 kc, ±3 db at 48 ips.

Circle 78 on Reader Service Card

Microwave Mixer Diode

Sylvania has announced a new silicon diode designed for microwave mixer applications in the L-band frequency spectrum. This covers the top of UHF range to 1500 mc. Designated the D-4097 it is a point contact type and exhibits a maximum conversion loss of only 5.5 db with a maximum output noise ratio as low as 1.5 times. This is the equivalent of a 2 db improvement in noise figure for a receiver whose IF amplifier noise figure would be 1.5 db, or a 13 per cent increase in range.

Circle 64 on Reader Service Card

New Diode

A new millimeter wave diode, the 1N2792, for low noise mixer performance at 70,000 mc has been announced by Philco Corporation's Special Components department. This recently declassified crystal is of integral wave guide construction with the germanium point contact structure mounted in a section of RG—98/U wave guide. A crystal noise figure maximum of 13 db with this hermetically sealed unit assures lowest possible noise performance at 70 kmc.

Circle 60 on Reader Service Card

Mechanical Convected Oven

The Electric Hotpack Company, Inc. announces a new forced air circulation oven designed for short heat testing, drying applications, encapsulization and other temperature testing and conditioning processes involving electronic parts and components. Temperature range is from 35°C to 350°C. (662°F.)

Circle 75 on Reader Service Card

Electronic Micrometer

New Model PDR Carson-Dice Automatic Electronic Micrometer gives direct measurements to the fifth decimal place, in 10 millionths of an inch. Precise measurements can be taken by unskilled operators. Works on any kind of material. Heavy one-piece casting has built-in fan and ventilating system to keep it at room temperature. Instrument can be readily moved about without affecting performance. Work capacity 3", throat depth 3". Weight 60 lbs. Available from J. W. Dice Company.

Circle 73 on Reader Service Card

Electric Furnace

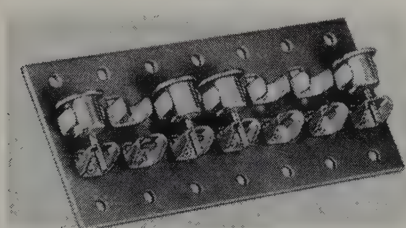
Those who do research investigations in ceramics or metallurgy, calling for ultra-high temperatures, will be interested in the announcement made by the Pereny Equipment Company of their new 5000°F. Electric Furnace. It is a carbon resistor type tube furnace of vertical design, identified as a Pereco Model "CT." Controls are capable of holding to plus or minus 20°F. at 5000°F. in inert gas atmosphere. The design also allows a choice of extremely rapid (room temperature to 4500°F. in approx. 2 hours) or any slower cycle heat-up.

Circle 76 on Reader Service Card

Diode Clips

Simple component installation and replacement of "top-hat" diodes or rectifiers can be achieved through the use of spring-tempered beryllium copper mounting clips recently introduced by the Atlee Corporation. Circuit contact is provided by an integral lug passing through the mounting surface either for connection to printed circuit leads, or for solder connection. Each clip pair exerts a strong retaining spring action on the body of the component, pressing the shell downward against a small projection in the clip which penetrates through films or oxides to clean metal, assuring circuits continuity under extreme conditions of stress.

Circle 88 on Reader Service Card



Semiconductor Preforms

Silver-Arsenic alloy preforms with a melting point of 1800°F are available from Accurate Specialties Co., Inc. The preforms are 99% silver, 1% arsenic, and in the form of spheres. They are available in the range .001" diameter to ⅛" diameter, with diameters and sphericity held as close as plus-or-minus .0001". High temperature alloy spheres will help automate the manufacture of high temperature silicon semiconductor devices, since a sphere will roll and lends itself to automatic loading into alloy jigs.

Circle 72 on Reader Service Card

Gold Plated Connectors

Molded Insulation Company, after more than a year spent in development under U.S. Army Signal Research & Development Laboratory contract, now offers a new line of connecting devices for micro-modules and other miniaturized circuitry. Low contact resistance (less than 0.005 ohms per contact); high insulation resistance; and polarization are incorporated in this connector series. Designed for the 0.050 printed circuit grid, they afford high contact density. The entire line conforms to Signal Corps Specifications SCL-6250.

Circle 90 on Reader Service Card

Automatic Decorator

A new double vertical fixture automatic spray machine, Model DVF, for high production painting has been developed by Conforming Matrix Corporation. It enables one operator to double the production heretofore requiring two hand sprayers. An increase of 200 to 500 pieces per hour should be accomplished on most jobs. The machine is entirely air operated and housed in its own booth Air filtering, cylinder and air valve lubrication, and water trap ejector are all automatic.

Circle 67 on Reader Service Card

Portable Tester

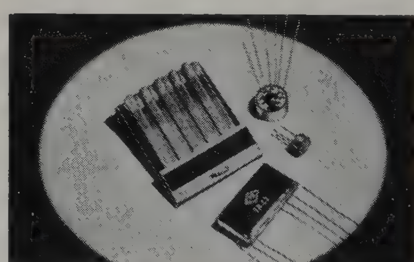
Model 902 Transist-O-Check portable battery-powered transistor tester has been announced by the Components Division, Transistor Specialties, Inc. Designed for simple and rapid testing of low and medium power transistors, the instrument checks D.C. beta, Icbo and Iceo, as well as the existence of collector-to-base and collector-to-emitter shorts. Tests are performed at a constant collector voltage of 6 V and cover a beta range of 0 to 200, Icbo from 0 to 50 microamperes and Iceo from 0 to 5 milliamperes.

Circle 86 on Reader Service Card

4-Stage Amplifier

A 4-stage amplifier is available from Centralab. Measuring only 0.531" in diameter and 0.228" in height, including the hermetically sealed case, the unit contains 12 resistors, 5 capacitors, and 4 transistors. The new unit, (upper right) known as the TA-12, has a gain of 73 to 78 db at 1 KC with 1000 ohm load. Its nominal input impedance is 2000 ohms. Signal to noise ratio is 42 db below 1 volt. Supply voltage is from a 1.3 volt mercury cell; current drain is 2.1 milliamperes maximum.

Circle 83 on Reader Service Card



Indium Ingot

Indium ingot in a range of ultra-high purities is available from High Purity Metals, Inc., for use in the manufacture of germanium transistors, diodes, rectifiers and other industrial applications. Available in two ingot sizes: 10 troy oz. and 100 troy oz. Applications include low melting alloys, glass sealing alloys, solder alloys, dental alloys, electrical contact alloys, shielding material in nuclear work, oxide film resistors, thermistors, rectifiers, photo-conductors, magnetic alloys, and chromium plating bath additives.

Circle 65 on Reader Service Card

Silicon Diodes

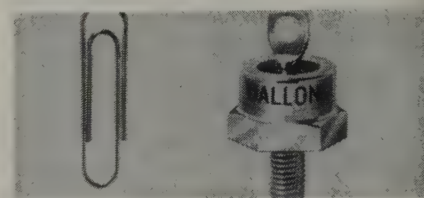
Designed to meet military specifications, Type Numbers RD2121-RD2124 are ideal for very fast computer switching applications. These diodes recover to 200K ohms in 0.2 microseconds and have a typical capacitance of 1.5 micro-microfared. These units are available in the standard subminiature glass package, from Rheem Semiconductor Corp.

Circle 77 on Reader Service Card

Silicon Rectifiers

20-35 Amp., 60-600 P.I.V. Silicon Rectifiers which exhibit extremely stable characteristics at high temperature are available from Dallons Semiconductors. The units contain solders within their construction which have a melting point in excess of 600°C. The 11/16" stud construction houses a pure silver, heavy spring lead anode assuring ruggedness and high resistance to shock and vibration. Electrical specifications show that these units have less than 5 ma reverse current and the maximum forward drop voltage at a test temperature of 25°C at 20 Amps., D.C. is .65 Volts.

Circle 66 on Reader Service Card



Ultrasonic Cleaning Unit

National Ultrasonic Corporation announces a new unit for use where average ultrasonic energy is required. Model 140 features a 7-gallon heavy gauge polished stainless steel tank 14¾" long, 11¾" wide and 10" deep. 27.5% of the tank bottom is covered with crystals. Actual radiating surface is 48 square inches. The 115-volt AC single-phase 60-cycle generator delivers an average power output of 250 watts and produces peaks of 1000 watts.

Circle 74 on Reader Service Card

Transistorized Power Supply

A well regulated dc power supply designed primarily for transistor circuit work and other applications where recurrent spikes and other transients would damage equipment under test is announced by Solidyne. Voltage and current meters are provided for accurate setting of output voltage and continuous monitoring of load currents. Voltage output is adjustable from 5 to 35 volts with a maximum current of 2 amperes. Model PS 201 is approximately 14 pounds in weight and occupies less than a square foot of bench space.

Circle 80 on Reader Service Card

VSWR Amplifier

An improved version of the VSWR Amplifier has been introduced by Narda Microwave Corporation. Model 441B is transistorized and battery-operated and has built-in provision to show the state of battery charge. Unit is supplied with nickel-cadmium batteries which recharge automatically when unit is plugged in. Bandwidth is 25-30 cps; the range is 72 db (60 db in 10 db steps, 11 db continuous). Attenuator accuracy is ±0.1 db per step; ±0.2 db maximum cumulative. Meter linearity is 1% of full scale.

Circle 85 on Reader Service Card

Transistor Test Set

Model 1803 Transistor Parameter Test Set, manufactured by Dynatran Electronics Corporation is designed for the measurement of the small signal parameters of both NPN an PNP transistors. The test set measures the "h" parameters for both the grounded emitter and the grounded base connections with an accuracy of 3%. Collector leakage current "Ico" can be read over a wide range of values from less than 5 millimicroamperes to 1 milliampere. The instrument is completely self contained and requires no additional accessories or instruments.

Circle 84 on Reader Service Card

Silicon Transistor

A new P-N-P alloyed silicon transistor with a guaranteed maximum 25°C Ico of muA at −12V is being offered by Crystalonics, Inc. Maximum Ico at 125°C is below 1uA. The typical Ico value at 25°C is 0.2muA, and 0.2uA at 125°C. The Beta spread is from 10 to 25. Maximum voltage rating is −25V. The unusually low Ico is achieved by extremely clean manufacturing conditions which also contribute to reliability of this transistor.

Circle 79 on Reader Service Card

Miniature Connectors

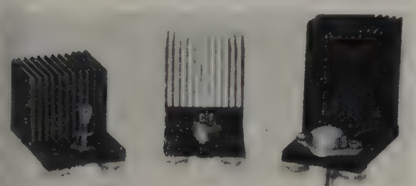
The Electronics Division of DeJur-Amsco Corporation has announced a group of miniature printed circuit connectors for printed tape cable or printed circuit board applications. Two series are included in the group, and are designated 600-4PCSC-13 for the 13-contact unit and 600-7-1 for the 18-contact unit. Both connectors have a current rating of 3 amps and feature staggered placement of contacts to assure ease of wiring.

Circle 89 on Reader Service Card

Semiconductor Radiators

Wakefield Engineering, Inc. announces a new line of R-5000 Semiconductor Radiators. The range of the Series is 5 watts to 100 watts dissipation ratings, with forced convection. Available in copper or aluminum. A surface machined flat to within 0.0002" is provided for mounting the semiconductors: transistors, rectifiers or zener diodes. Screw holes for mounting any semiconductor type can be provided.

Circle 82 on Reader Service Card



Rectifier Analyzer

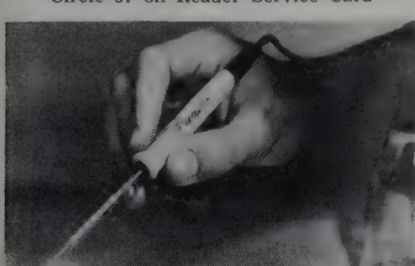
Wallson Associates, Inc. has announced a completely self-contained Dynamic Rectifier Test Set for incoming inspection, on-line testing and laboratory use. Forward current and reverse voltage controls are independently adjustable. Known as the Model 138A, the forward current range of this unit is 0-1 and 0-5 amperes D.C. average, with a reverse voltage peak of 0-1000. It measures a forward drop range of 0-1/5 volts and a reverse current range of 0, .05, .5, 5, 50 ma average.

Circle 81 on Reader Service Card

Low Wattage Soldering Iron

M. M. Newman Corp., pen-shaped PRECISION Miniature Soldering Iron measures 6½" long and operates on 110-115 volts without a transformer. It has a 50 megohm insulation between element and tip, ideal for use around semiconductors. Heat-up time required is about 45 seconds and a sealed element maintains constant temperature at approximately 626°F.

Circle 87 on Reader Service Card



Industry News

CONFERENCE CALENDAR

The Following March 1960 Meetings Are Scheduled:

March 4-5 American Physical Society, Rice Institute, Houston, Texas. Sponsored by American Institute of Physics.

March 9-11 Temperature Measurement Symposium, Deshler-Hilton Hotel, Columbus, Ohio. Sponsored by Instrument Society of America.

March 16-18 Electronic Industries Association Spring Conference, Statler-Hilton Hotel, Washington, D. C.

March 21-24 IRE International Convention, Coliseum & Waldorf-Astoria Hotel, New York City. Sponsored by all PG's. For Information: Gordon K. Teal, Chairman, 1960 Technical Program Committee, IRE, 1 East 79th Street, New York 21, N. Y.

March 24-25 1st National Symposium on Human Factors in Electronics, Bell Telephone Laboratories Auditorium, 463 West Street, New York City. Sponsored by PGHFE. For Information: Robert R. Riesz, Bell Telephone Laboratories, Murray Hill, N. J.

March 27-31 Scientific Apparatus Makers Association, Annual Meeting, Boca Raton Hotel, Boca Raton, Florida.

(Continued on page 67)

Market News

Sales

The Electronic Industries Association has reported the factory sales of transistors for the first ten months of 1959 as being approximately 85% more in volume and over 110% in dollar value above the same period in 1958.

	Units	Value
1958	35,982,123	$ 83,692,052
1959	66,621,426	$176,447,266

The Electronic Production Resources Agency has reported a tremendous increase in the sale of military transistors during the first six months of 1959. The Department of Defense spent $37,190,000 for the first half of 1959 which alone almost equals the $41,300,000 military transistor sales for the entire year of 1958.

The United States Department of Commerce has reported that the exports of semiconductors for the first nine months of 1959 was $6,461,000 which was almost 12% above the $5,772,000 exported during the same period in 1958.

The Federal Government's Electronic Resources Development Agency has planned the military transistor requirements up to the end of 1961. It expects production of 38 million units worth an estimated $210 million.

Philco Corporation and CBS Electronics have signed a cross-license agreement covering the manufacture and sale of semiconductors.

Prices

Texas Instruments Inc., has introduced two new silicon mesa transistors which are said to be capable of a minimum power output of 500 mw at 70 mc. The 2N715 sells for $32.50 each in quantities of 100 to 999 and the 2N716 in the same quantities for $42.25 ea. The company also is marketing a line of fast switching, high voltage silicon mesa diodes that are expected to have application in the computer industry. The price of their 1N914 is $6.00 in quantities up to 99 and $4.50 in quantities from 100 to 999. Similarly type 1N916 is $8.04 and $6.02 depending on the quantity.

Hughes Aircraft Corp., has announced price reduction of up to 10% on all PNP fused junction transistors. The 2N1228 to 1234 line was formerly $25.50 each in lots of 100 to 999 and now the price average is $23.00.

Microwave Associates, Burlington Mass., is producing a 1N630 tripolar coaxial diode for use in microwave video receivers to sell for $46.55 each in quantities of 1-9. Their reversed polarity Si diodes MA-450A through MA-450E intended for use in low-noise parametric amplifiers, single sideband modulators and RF limiters are priced in quantities 1-9 at

MA-450A to C at $ 30.00 each
MA-450D to C at $ 75.00 each
MA-450E to C at $135.00 each

Bendix Aviation Corp., Red Bank, N.J., Division, is marketing a 2N1011 military type switching transistor priced at $10.50 each in quantities up to 99 for the military.

NEW SERVICE NOW AVAILABLE

Beginning with this issue, the sales department of SEMICONDUCTOR PRODUCTS is making a new source of information available to all firms interested in being kept up to date on materials or equipment for producing semiconductor devices. If you wish to receive all new literature on silicon, germanium, chemicals, machinery, or other such materials, circle #99 on the reader-service card. Your name will be placed on a special list which will be forwarded to all such suppliers. As these suppliers have news available in their field, you'll be notified by them immediately. This service is restricted to firms manufacturing semiconductor devices or firms contemplating entering into production within 120 days.

General Electric has samples of a new 1000mc germanium tunnel diode for research laboratories and equipment manufacturers. The price has been set at $60.00 each.

Crystalonics Inc., Cambridge, Mass., has priced their symmetrical Si PNP bilateral switching unit C101-3 and their PNP alloyed Si unit C112, all with a claimed cut-off level of about 0.8 mc, as follows in quantities of 100

Type	Beta Range	Price each
C101	minimum of 6	$14.40
C102	minimum of 10	$19.80
C103	minimum of 15	$31.50
C112	spread from 10-25	$22.00

Expansion

Fairchild Semiconductor Corp., Mountain View, Cal., has leased a 10 acre site at the outskirts of San Rafael, Cal., on which they plan to erect a 50,000 square foot diode manufacturing plant. The new plant is expected to be in operation by June 1960. Until that time Fairchild will immediately initiate its diode production program in leased quarters in San Rafael.

North American Electronics, Inc., Lynn, Mass., manufacturers of silicon diodes, has moved its plant and office facilities to a 26,000 sq: ft. area which they have leased.

Suppliers

Intertron Inc., Scranton, Pa., is producing transistor bases with glass to metal hermetic seals.

Financial

Erie Resistor Corp., has declared a 4% stock dividend to holders of common stock. The 1959 total dividend was 10¢ cash plus 4% stock as against 15¢ and 4% stock in 1958.

Britton Electronics Corp., Queens Village, L.I., N.Y. a semiconductor firm, is expecting to offer 225,000 shares of common stock at $1.00 a share. Proceeds will be used to finance expansion into the silicon rectifier and transistor field.

Bendix Aviation Corporation has reported a net income for the fiscal year ending Sept. 20, 1959 of $27,400,000 or $5.37 a share. These earnings were 29% higher than the previous year's net income of $21,171,902 or $4.18 a share. The company reported that over 40% of the Corporation's output was electronic in character.

Distribution

National Semiconductor Corp., Danbury, Conn., has appointed Milgray Electronics as the first exclusive distributor for their transistors.

The Semiconductor Division of Sylvania Electric Products Inc., has opened a new sales office in Wilmington, Mass., to serve the New England area.

Semiconductor Division of Hoffman Electronics Corp., has relocated two of its West Coast sales offices. The Los Angeles area sales office has been moved to the firm's new West Coast manufacturing and research plant in El Monte, Cal. The San Francisco area sales office is now located in San Carlos, Cal.

(continued)

Market News

(continued)

Contracts

- - - Microwave Associates Inc., Northwest IndustrialPark, Burlington, Mass. Semiconductor Device: Type 1N23C, MIL-E-1/295B and MIL-E-1D, QPL, N126-092164 (IFB 126-326-60) - - - 34810 ea. - - - $27500

Hoffman Semiconductor Division, Hoffman, Electronics Corp., Evanston, Ill. Semiconductor Device, Diode. Contract No. 86204 (PR No. SC-36-039-60-10620-B1 (05202-PP-60-B1-51) - - - 1456 ea. - - - $42115

- - - Transitron Electronic Corp., Wakefield, Mass. Semiconductor Device, Diode: JANIN251 - - - Various Quantities - - - Contract No. 86208 (PR No. SC-36-093-60-10619-B1) (05209-PP-60-B1-B1) - - - $33942

Texas Instruments Inc., Dallas, Tex., $23,764.02 for 1 item of transistors, type 2N335, IFB-534

Philco Corp., Lansdale, Pa., $5,600 for 1 itme of transistors. IFB-522

A split award to Philco Corp., Lansdale, Pa., $8,027.50 for 1 item of transistors; General Electric Co., Liverpool, N.Y., $660.00 for 1 item; Sylvania Electric Prods., Woburn, Mass., $85.00 for 1 item IFB-389,closed Oct. 29.

Industry News

(from page 62)

The National Bureau of Standards has decided to follow the recommendations of the International Committee on Weights and Measures to use new prefixes for denoting multiples and sub-multiples of units. The Committee adopted the prefixes at its meeting in Paris in the fall of 1958. In addition to the 8 numerical prefixes in common use, which are given in the table below, the Committee expanded the list by adding the 4 prefixes marked with an asterisk. Thus, for example, 10^{-12} farad is called 1 picofarad, and is abbreviated 1 pf.

MULTIPLES AND SUB-MULTIPLES	*PRE-FIXES*	*SYM-BOLS*	*PRO-NUN-CIATION*
1 000 000 000 000 = 10^{12}	tera*	T	ter'á
1 000 000 000 = 10^{9}	giga*	G	ji'gá
1 000 000 = 10^{6}	mega	M	
1 000 = 10^{3}	kilo	k	
100 = 10^{2}	hecto	h	
10 = 10	deka	dk	
0.1 = 10^{-1}	deci	d	
0.01 = 10^{-2}	centi	c	
0.001 = 10^{-3}	milli	m	
0.000 001 = 10^{-6}	micro	μ	
0.000 000 001 = 10^{-9}	nano*	n	na'no
0.000 000 000 001 = 10^{-12}	pico*	p	pi'co

RESEARCH & DEVELOPMENT

Sylvania Electric Products Inc. has raised the temperature capabilities (up to 150° C) of its full line of S and X-band microwave diodes, it has been announced by Roger A. Swanson, product sales manager—microwave diodes, of the company's Semiconductor Division.

Low cost production of ultrapurity hydrogen from dissociated ammonia is now possible with a Hydrogen Palladium Diffusion Purifier (U.S. Pat. No. 2,911,057) built by the Chemical Division of Engelhard Industries, Inc. Impurities are so low that they cannot be detected by any known methods of analysis, the firm claims. Potential applications for the equipment exist in the chemical industry, petroleum and petrochemical processing, manufacture of semiconductor devices and other electronic components, and in the atomic energy field.

New Literature

General Chemical Division of Allied Chemical has issued an excellent color brochure on their Baker & Adamson Products. "Electronic Grade Chemicals for the Electronic Industry" gives specifications for "Electronic Grade" chemicals for the production of semiconductors. Contains photos and descriptive information, as well as a list of General Chemical sales offices throughout the country.

Circle 100 on Reader Service Card

Available from Alda Plastics is a folder describing their plastic fabrication facilities. These include machining, forming, bending, welding, silk-screening and engraving to exact specifications in the engineering and electronics industries. Specialists in short runs, graphic flow panels, industrial models, housings.

Circle 101 on Reader Service Card

Available from Bendix Aviation Corp. Semiconductor Division are data sheets on their newly-improved 2N1031, A, B, C and 2N1032, A, B, C power transistor series, and on their new military-type transistor, 2N1120, designed to meet specification MIL-T-19500/68 (Sig. C).

Circle 102 on Reader Service Card

A catalog sheet describing their new 300 Series Transistorized Digital Systems Modules has been issued by Navigation Computer Corp. These new card modules have been designed with the system in mind; utilizing the latest techniques in printed circuit packaging.

Circle 103 on Reader Service Card

Technical Bulletin P-5a—"Miniaturized Printed Circuits" is available from Photocircuits Corporation. Contains clear, concise and complete information on how the elimination of "lands" or pads around plated-thru holes permits substantial size reduction of printed circuit boards and greater component densities. It describes how the barrels of the holes are used for solder joints without sacrifice of reliability, repairability, pull strength or insulation resistance.

Circle 104 on Reader Service Card

A new data sheet on RF chokes is available from Essex Electronics, Division of Nytronics, Inc. The new RF Chokes, called Wee-Ductors, are so small that 200,000 can be packed to a cubic foot. The data sheet contains a detailed description of the electrical parameters for the complete line.

Circle 105 on Reader Service Card

A bulletin describing and illustrating the SIE Airborne Transistorized Power Supplies, Models TPC-18A and 19A, includes applications, schematic drawing and specifications. Products are designed for direct, plug-in replacement of D-10A

(Continued on page 70)

New Literature

(from page 68)

dynamotors as the power supply for aircraft communications and navigation receivers, using a transistor multi-vibrator circuit to deliver voltage at high efficiency with good regulation and provide protection against overload or short-circuit.

Circle 106 on Reader Service Card

Tempo Instrument Incorporated offers Engineering Bulletin 5905, an 8-page illustrated catalog containing complete technical data on the company's line of Electronic Time Delay Relays. Bulletin includes a comprehensive description of circuit design, manufacturing and assembly process, standard and special type specifications, and detailed data on sizes, available mounting arrangements, weights and terminal styles.

Circle 107 on Reader Service Card

An eleven page Bulletin No. 102 entitled "Large Single Metal Crystals," which describes standard specimens as well as unusual shapes and special crystal orientations, is available from Flow Corporation. A large number of randomly oriented single metal crystal specimens in aluminum, cadmium, copper, lead, nickel, silver, tin and zinc are now available for immediate delivery in many standard sizes and shapes.

Circle 108 on Reader Service Card

Electronic Research Associates, Inc., announces the availability of a catalog sheet which describes the company's Zener Voltage Tester, Model DT100. The sheet provides full descriptive information on the unit, specification data, and current pricing information.

Circle 109 on Reader Service Card

The new line of Radio Receptor selenium rectifier "Flats," is described in an 8-page brochure presenting the basic rectifier information, product description, and methods of selecting the right rectifier for a circuit. Prices are also included in the bulletin. Designed primarily for applications in the electronic, entertainment, and special products fields, they are available in all circuit types from 15 to 600 volts and can be operated into a resistive or capacitive load.

Circle 110 on Reader Service Card

A brochure describing mechanical and air-operating clamps for holding masks and parts, and standard and special fixtures used to speed up production in color decoration of mass produced products, is offered by Conforming Matrix Corporation.

Circle 111 on Reader Service Card

United States Dynamics Corporation, Industrial Equipment Division, announces the publication of new literature on its Dynadryer and Dyn-Oxo equipment. Includes general descriptions of operation, technical data, product applications, and a simplified customer questionnaire. The Dyn-Oxo Purifier provides for the catalytic combination of oxygen and hydrogen with purification of a variety of gasses. The Dynadryer Automatic Air and Gas Dryer provides a continuous supply of clean, oil-free, dried air or other gasses automatically at a dewpoint of lower than −100°F.

Circle 112 on Reader Service Card

A two-color four page folder has been prepared by Schweber Electronics to aid buyers and engineers in the selection of Fairchild Semiconductor diffused silicon mesa transistors. Complete application and performance characteristics are outlined in a concise reference form.

Circle 113 on Reader Service Card

A new 4-page, short-form catalog, illustrating their newly completed line of precision electronic welding equipment, is now available from Weldmatic Division of Unitek Corporation. It contains descriptions, design and performance features, prices, and illustrations of all Weldmatic stored-energy power supplies, column-mounted welding heads, and light-to-heavy-duty handpieces. Several typical set-ups are shown to illustrate the versatility of the equipment.

Circle 114 on Reader Service Card

Bulletin Z-102, describing solder clad base tab stampings used in making ohmic junctions to germanium or silicon junction transistors, is now available from Accurate Specialties Co., Inc. Completely describes base tab stampings. An illustration depicts the cladding usually in a ratio of 6:1. A photo of typical stampings is also included.

Circle 115 on Reader Service Card

Allied Radio Corporation announces the release of a new "Allied Connector Directory." Containing comprehensive listings of the most widely used electronic connectors, this 16-page directory is offered as a convenient buyer's guide for manufacturers, research labs, engineers, designers, etc. Alphabetically arranged by manufacturers, Amphenol, Cannon, Cinch-Jones, Harvey Hubbell, and Hart & Hegeman connectors are listed in numerical order for easy reference.

Circle 116 on Reader Service Card

A bulletin on Fotoceram micro-module wafers is available from the Receiver Bulb Sales Department of Corning Glass Works. The tiny wafers are produced by chemically machining glass to "micro accuracy" from a photographic reduction, then converting it to a ceramic. The bulletin says they are non-porous, dimensionally stable and shock resistant and that designs other than four patterns in stock can be produced economically "in a matter of days."

Circle 117 on Reader Service Card

A new 8-page booklet, describing the Cobehn Spray-Clean Technique, has been issued by Cobehn, Inc. The booklet describes and illustrates how to achieve the ultimate in chemical cleanliness for such components as transistors, diodes, vacuum tubes, jewel bearings, pivots, electrical contact points, miniature slip-ring assemblies, high fidelity transformers, dynamotor potentiometers, and other precision parts in the electronic, electromechanical fields.

Circle 118 on Reader Service Card

Electrical and mechanical data, performance characteristics, and product features concerning a new series of PNP silicon alloy transistors are treated comprehensively in three technical bulletins available from National Semiconductor Corporation. The transistors designated by type numbers 2N1440, 2N1441, and 2N1442, are in accordance with JEDEC 30.

Circle 119 on Reader Service Card

Index to Advertisers

LOWEST COST PER GRAM

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NEW MATERIAL RESEARCH

SPECIFICATIONS TO ORDER

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KNAPIC specializes in Silicon and Germanium Crystals for Semiconductor, Solar Cell and Infrared uses

lajor manufacturers of semiconductor devices have found hat Knapic Electro-Physics, Inc. can provide production uantities of highest quality silicon and germanium monorystals far quicker, more economically, and to much tighter pecifications than they can produce themselves.

'he reason? Knapic Electro-Physics are *specialists* with acelerated experience in growing new materials to specification.

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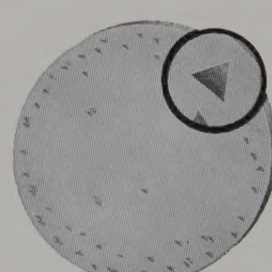
tremely low dislocation densities.
ght horizontal and vertical resistivity tolerances.
ameters from 1/4" to 2". Wt. to 250 grams per crystal. Individual crystal lengths to 10".
w Oxygen content 1×10^{17} per cc., 1×10^{16} for special Knapic small diameter material.
ping subject to customer specification, usually boron for P type, phosphorous for N type.
fetimes: 1 to 15 ohm cm.—over 50 microseconds; 15 to 100 ohm cm.—over 100 microconds; 100 to 1000 ohm cm.—over 300 microseconds. Special Knapic small diameter aterial over 1000 microseconds.

Specification Sheets Available



Dislocation density, Knapic silicon monocrystals grown by a modified Czochralski technique: Crystal diameter to 3/8"—None; 3/8" to 3/4"—less than 10 per sq. cm.; 3/4" to 1 1/4"—less than 100 per sq. cm.; 1 1/2" to 2" less than 1000 per sq. cm.

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Sprague, the pioneer in the production of solid-electrolyte tantalum electrolytic capacitors, now offers prompt delivery on production quantities of all standard ratings. New expanded facilities end production delays in your assembly of minified transistor circuits.

Typical of these Tantalex Capacitors is the Type 150D shown above. Its tiny sintered anode is impregnated with a solid, non-corrosive, semi-conductor material which cannot leak under any circumstance. It combines true miniaturization with electrical stability previously unobtainable in an electrolytic capacitor of any type.

Thermal coefficient of these capacitors is sufficiently low and linear so that for the first time a circuit designer can think of an electrolytic in terms of parts per million capacitance change. Nominal value is +500 ppm/°C. The capacitor may be used without derating over a range from −80°C to +85°C, or to 125 °C with appropriate derating, a temperature at which no other electrolytic has proved useful.

Solid construction permits the Type 150D to withstand the severe shock and vibration encountered in missile and ballistic applications. Hermetic sealing makes it completely immune to humid atmospheric conditions.

Complete performance data covering the wide range of sizes and ratings are in Engineering Bulletin 3520C, available on letterhead request to the Technical Literature Section, Sprague Electric Company, 467 Marshall Street, North Adams, Massachusetts.

★ ★ ★

DON'T FORGET!—*Sprague also offers prompt delivery on production quantities of all other types of tantalum capacitors including tubular foil and sintered anode designs. For pilot quantities of popular ratings at factory prices, see your Sprague industrial distributor.*

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